EVALUATION OF THE IMPACTS OF COMMON LANE UTILIZATION OF HEAVY AND LIGHT VEHICLES ON PERFORMANCE OF ADDIS ABABA MIDBLOCK RING ROADS

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ACRONYM

ANOVA Analysis of Variance

ERA Ethiopia Roads Authority

FFS Free Flow Speed

FHWA Federal Highway Administration

HH Heavy vehicles with Heavy vehicles

HS Heavy vehicles with Light vehicles

LOS Level of Service

MMLOS Multimodal Level of Service

MVC Motor Vehicle Crushes

MVTC Motor Vehicle Traffic Collision

PCE Passenger Car Equivalent

PIC Personal Injury Collision

SPSS Statistical Package for Social Science

SS Light vehicles with Light vehicles

TRB Transportation Research Board

APPROVAL PAGE

This Msc thesis entitled with **"Evaluation of The Impacts of Common Lane Utilization of Heavy and Light Vehicles on Performance of Addis Ababa Midblock Ring Roads"** has been approved by the following examiners in partial fulfillment of the requirement for the degree of master of Science in **Road and Transport Engineering**.

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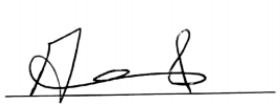
1. Dr. Ashenafi Aregawi  _____

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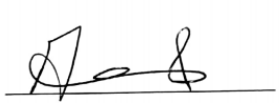

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I, Anbessa Bekele, declare that this thesis is my own original work that has not been presented and will not be presented by me to any other University for similar or any other degree award.

_____

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ABSTRACT

Standard speed limit on Addis Ababa Midblock ring road is 80km/h. However, most of the vehicles speed exceed this limit or short fall this limit; because, heavy vehicles are complex in operation than light vehicles and heavy vehicles cover wide space to change a lane. Severity of crash between heavy and light vehicle is higher than crash between light and light vehicles or crash between heavy and heavy vehicles.

The main objective of this study is to identify impacts of common lane utilization of heavy and light vehicles on the performance of Addis Ababa midblock ring roads. Pre-tested self administered questionnaire, developed format to collect secondary data and scenarios were developed from collected videos. Statistical analysis was used to evaluate the result. *Out of six causes of crash* (illegally using opposite lane, unavailability of enough headway, illegal overtake, unacceptable driving backward, illegal lane change and vehicle out of control) majority (40.4%) were caused by illegal lane change. Out of three types of vehicle-vehicle conflict (heavy-heavy, heavy-light and Light-Light); 46% were heavy-light vehicle conflict, 44% were Light-light vehicle conflict and 9.6 % were heavy-heavy vehicle conflict. From this; frequency of heavy-light vehicle conflicts was higher than other combinations (Light-light vehicle conflict and heavy-heavy vehicle conflict).

54% of Light-light vehicle conflicts were because of illegal lane change and 38% of heavy-light vehicle conflicts were because of insufficient headway. These indicate that; light vehicles following heavy vehicles enforced to change lane. *From video analysis result*, when light vehicles following heavy vehicles was 67.6km/hr but the mean speed of rear vehicles speed becomes 80.77km/hr when light vehicles follow light vehicles. These specify that; road segment with light vehicle following light vehicle is significantly improving performance as compared to light vehicle following heavy vehicle. From three scenarios developed by simulation analysis (VISSIM 9); In scenario 1(Light vehicle follow only Light vehicle, removing heavy vehicles from the midblock ring road) there was no average vehicles delay and only 0.21 sec. total vehicles delay were observed. In scenario 2(Lane restriction, restricting heavy vehicles to the outer lane of the midblock ring road) average vehicles delay was 0.06sec, and 50.43 sec total delay were observed. In scenario 3 (common lane utilization, both light and heavy vehicles utilize the same lane) 1.2sec average vehicles delay and 200.2 sec total vehicles delay were detected. From these when light and heavy vehicles utilize the same lane average and total vehicles delay were higher than other scenario which shows that performance of the ring road decreased in common lane utilization option. The research concludes that presence of heavy vehicles with light vehicles on the same lane of Addis Ababa midblock ring road decreases performance of the ring road. Therefore it is recommended to develop policy which is lane restriction for heavy and light vehicles on midblock ring roads

Key words: Common lane utilization, Heavy and Light vehicles, Addis Ababa Midblock ring road and lane restriction.

CHAPTER ONE

INTRODUCTION

1.1 Background

The Addis Ababa Ring road was initiated as part of the city's commitment towards implementing the city master plan and enhancing peripheral development.

Addis Ababa ring roads connect all the five main gates in and out of Addis Ababa with all other Regions (Jimma, Bishoftu, Asmara, Gojjam and Ambo).

The main use of Addis Ababa ring road is that heavy vehicles entering the city of Addis Ababa from the five main radial routes will be diverted into the ring road either to bypass Addis Ababa completely or to transfer to another radial route to suite their eventual destination and in doing so avoid the city center.

This ring road have sidewalk with 3m width, frontage ring road width of 6.6m, separator between midblock and frontage of 1.7m, mainline (midblock) with width of 7.2m and median which is 3m width on one side and the same parameter and width on the other side.

Nowadays traffic congestion has become one of the main societal and economical problems in urban areas related to transportation industries both in developed and developing countries.

Ring roads of Addis Ababa traffic flow is under high congestion condition mainly morning and afternoon. In the last five decades, a wide range of traffic flow theories and models have been developed to minimize problem of traffic congestion(1).Traffic congestion is mainly observed during peak hours.

In some midblock lane sections, there are visibilities problems for light vehicle drivers caused by turning heavy vehicles.

This causes vehicle – vehicle conflict and affects the capacities of the roads and intersections capacity. Lane changing heavy vehicles also one of reasons for vehicle-vehicle conflict

In ring roads; frontage lane along the ring road traffic flow may be affected by on street parking. Therefore the thesis focuses on the midblock segment.

Midblock segment is a lane with no on street parking permission and is with high speed limit than frontage segment.

At the study area (Addis Ababa ring roads) the speed limit for midblock lane is 80km/hr and 50km/hr for frontage lane. Those ring road segments appropriate for video data collection were selected for this study.

Now day severe crashes and congestion occur on mid-block segments of ring roads. Proper usage of midblock lane on ring roads can improve safety and operational efficiency at intersections, usually for traffic flow management or to improve safety (2). Thus, the study of traffic flow on midblock section of ring roads aims to understand traffic behavior in order to answer the following basic questions: how to manage traffic congestion, what causes congestion and traffic safety. These factors which could contribute in influencing traffic flow on midblock lane of ring road and flow in the network need deep investigation. For this reason, understanding what type of flow is occurring in a given situation is helpful to decide the most relevant method for analysis and description of the problem. In addition to this, managing traffic in congested road networks requires a clear understanding of traffic flow operation and causes of congestion (3), indicated that fuel consumption of a vehicle increases approximately by 30% under heavy congestion. In order to reduce these losses, it is required to create an efficient method to resolve traffic congestion and reduce the delay time (4). The dynamic vehicular delay at intersections is a major current concern, because the standard static network equilibrium formulation fails to capture essential features of traffic congestion**.**

Addis Ababa has high standard ring roads, which most of them facing high volume of traffic with different size of vehicles. This vehicle type heterogeneity has impact on speed of vehicles and safety; generally this heterogeneity highly affects performance of the ring road.

There are two options for every vehicle to travel along this ring road; midblock and frontage roads along the ring roads. Even though the main reason for congestion, conflict and pollution is common lane use of heavy and light vehicles, little attention has been paid to the composition of vehicles using those roads. Generally impact of common lane use of heavy and light vehicles on the performance of the road was not much considered. Having this in to consideration the current study aimed to assess the impact of common lane utilization of heavy and light vehicles.

1.2 Statement of the Problem

It is difficult to have normal traffic flows and good road performance at Addis Ababa ring road, which is more dependent on vehicle composition using the ring road. This problem will continue and it may worsen in the future due to the rapid growth of number of vehicles in Addis Ababa.

Heavy vehicles adversely affect traffic flow because, they are longer than light vehicles and therefore occupy more roadway space, and they have poor operating capabilities than light vehicles, particularly with respect to acceleration and deceleration which are the main cause of congestion and delay.

Poor Pavement condition, invisible pavement marking, damaged traffic signs and illegally crossing pedestrians were other problems seen on Addis Ababa ring roads.

On Addis Ababa ring roads junction traffic congestion is common. The traffic police need to intervene in the situation to regulate the traffic flow; but currently the situation becomes sever. Therefore, it is vital to evaluate effect of traffic composition.

Figure 1: Heavy Vehicle has damaged many light vehicles in front of it

(Source: Kolfe keraniyo sub city police station)

Figure 2: One of the many damaged light vehicles by one dump truck

(Source: Kolfe keraniyo sub city police station)

1.3 Scope of the Study

This research was for day counted traffic flow and covers evaluation of impacts of common lane utilization of heavy and light vehicles on performance of Addis Ababa midblock ring roads. In addition to impact of common lane utilization; impact of poor pavement condition, invisible marking and reflectors, road geometry and illegally crossing pedestrians were considered. In this research level of service of the ring road, road safety, mobility and reliability were analyzed.

Inclusion

- All vehicles with greater than or equal to four tyre were included.
- All ring roads segment having both midblock & frontage and appropriate to collect video data were included.

Exclusion

- Pedestrian, Bicycles, motor cycles and any malfunctioned (stop working) vehicles were excluded.
- Ring roads segment with not separated midblock and frontage were excluded
- Ring roads which are inappropriate to collect data or to mount camera were excluded

1.4 Objectives

1.4.1 General objective

To evaluate the impacts of common lane utilization of heavy and light vehicles on the performance of midblock section of Addis Ababa ring road.

1.4.2. Specific objectives

- To examine impacts of the heavy vehicles on the performance of the Addis Ababa ring road
- To identify the impacts of road condition and geometry on performance of Addis Ababa ring road
- To Evaluate the lagging vehicle performance when following slowly moving light or heavy vehicle
- To evaluate the main reasons causing vehicle to vehicle conflict

CHAPTER TWO

LITERATURE REVIEW

2.1 Definition

2.1.1Car following or common lane utilization

Car following behavior describes the behavior of vehicles while following the vehicle in front of it on the same lane.

Overall congestion increases as the number of trucks increase, and as trucks are involved in incidents or crashes, the result is often much more catastrophic than if only cars are involved. Crash severity generally increases where trucks are involved, resulting in greater damage to smaller vehicles and their occupants and to roadway appurtenances (6).

Trucks have slower braking and acceleration rates than passenger cars, which increases frustration to drivers in congested situations. Additionally, the lack of maneuverability of trucks relative to passenger cars contributes to crashes (7, 8).

For several reasons trucks contribute more to congestion than do cars: they occupy more road space, they are slower to accelerate and decelerate and to negotiate turns, and they obscure vision more. A standard procedure to account for the greater impedance of trucks is to use a Passenger Car Equivalent (PCE). Typical PCE values are 1.5-2 for single-unit trucks **(Includes two-axle, four-tire trucks and other single unit trucks i.e. - it does not carry its cargo in an attached trailer)** and 2-3 for combination vehicles. The PCE factor has two limitations for assessing the merits of separating cars and trucks. One is that the delay created by a vehicle may depend on the composition of vehicles in the traffic stream (9) . PCE of trucks is an increasing function of the fraction of trucks (10).

A second and more fundamental limitation is that while the PCE measures the overall delay created by trucks it does not account for their separate effects on cars and trucks, these effects are not yet well understood (11).

Traffic congestion occurs when a volume of traffic or modal split generates demand for space greater than the available road capacity; this point is commonly termed saturation.

There are a number of specific circumstances which cause or aggravate congestion; most of them reduce the capacity of a road at a given point or over a certain length, or increase the number of vehicles required for a given volume of people or goods (12).

In addition to congestion, trucks create safety hazards for other vehicles. Several truck characteristics suggest that these hazards are greater for cars than trucks.

Long trucks have extensive blind spots and drivers may have difficulty seeing smaller vehicles beside and behind them. Trucks obscure a wider field of view for light vehicle drivers and the blockage is magnified when a column of trucks is traveling in the same lane.

Trucks block sight of other vehicles as well as roadside and overhead signs; although the extent of this problem has not been studied (13). On bad roads and in bad weather trucks throw up water and debris that may cause vehicle damage and obscure vision. Trucks create obstacles and hazards when they lose their loads or blow a tire and trucks with heavy axle loads cause road damage which, over time, may reduce safe driving speeds and increase wear and tear for light vehicles.

In addition; the frequency of lane changes is used as a measure of safety impacts. Intuitively, as the frequency of lane changes increases, the likelihood of a collision increases (14).

This measure can be obtained from the total lane changes divided by the total traffic volume. Many previous studies have identified the relationship between frequency of lane changes and crashes. They found that as the frequency of lane changes increase, the likelihood of crashes also may increase. Similarly, speed differential between trucks and non-trucks can be also used as a safety measure. Identifying these impacts is very important to establish causal factors for vehicular crashes and for strategy evaluations.

The behavior of light vehicle drivers is affected by the presence of trucks in ways that can affect safety. There is some evidence that car drivers maintain longer headways when following trucks than cars (15). Car drivers are more inclined to overtake trucks than cars and to overtake them more quickly. Car drivers experience psychological discomfort from the presence of trucks particularly in bad weather and at intermediate traffic volumes when both the probability and potential severity of collisions is elevated (11).Large trucks are prohibited on many highways from using certain lanes.

Most restrictions in the U.S. apply 24 hours a day to ease enforcement and driver compliance. Restrictions are sometimes voluntary, and many states do not attempt to enforce those that are mandatory (16).

The entry of heavy vehicles that is, vehicles other than passenger cars (a category that includes light trucks and vans) into the traffic stream affects the number of vehicles that can be served. Heavy vehicles are vehicles that have more than four tires touching the pavement (17).

Although speed is a major concern of drivers as related to service quality, freedom to maneuver within the traffic stream and proximity to other vehicles are equally noticeable concerns. These qualities are related to the density of the traffic stream. Unlike speed, density increases as flow increases up to capacity, resulting in a measure of effectiveness that is sensitive to a broad range of flows (17).

The free flow speed is used to determine the urban street class and to estimate the segment running time. If FFS cannot be measured in the field, the analyst should attempt to take measurements on a similar facility in the same area or should resort to established local policies. Lacking any of these options, the analyst might rely on the posted speed (17).

Research by (18) indicates that vehicle length contributes negatively to highway flows. She analyzed different third-order-polynomial models of flow versus density interacted with other explanatory variables, and the elasticity of flow with respect to average vehicle length was estimated to be 17.4%. LDTs (light-duty truck) starting pass at an intersection are expected to add to lost time, making less effective use of pass time and adding to congestion and delays.

Finally, it was hypothesized that the presence of a light-duty truck in front of a passenger car causes the passenger-car driver to be more cautious because of the LDT's large size and the resulting diminished sight distances. This may cause the headways of passenger cars to be larger; and, if so, this increase must be considered in the overall capacity reduction due to LDTs.

(3, 19) indicated that fuel consumption of a vehicle increases approximately by 30% under heavy congestion. In order to reduce these losses, (4) suggested that it is required to create an efficient method to resolve traffic congestion and reduce the delay time.

Studies vary on how lane restrictions affect traffic operations. It is, Concluded that providing separate lanes for trucks enhances performance as measured by speeds, fuel consumption and emissions (20). Not surprisingly, passenger vehicles benefit more from vehicle separation during peak hours when congestion is high and on highway sections with extended upgrades (21, 22). Lane restrictions are found to be more effective on highways with three or more lanes in each direction than on highways with only two (23) and on freeways with limited access. Studies differ as to whether trucks should be restricted to the outer lane (22) or inside lane (24).

Many highways have different speed limits for cars and trucks. The practice is controversial and arguments are made both for and against differential speed limits.

Inferior maneuverability and braking capabilities of trucks militate in favor of lower speeds, at least in mixed traffic, although as noted above truck drivers tend to have superior vision and driving skills that enhance truck safety.

Differential limits may increase speed variance and induce more frequent lane changes that increase the rate of car-into-truck rear-end collisions and sideswipes, but reduce other types of accidents such as truck-into-car rear-end collisions (25).

Evidence on the safety effects of differential speed limits is relatively sparse. There is little difference in overall accident rates or severity between U.S. states with uniform speed limits and differential limits although the types of collisions and the roles of cars and trucks appear to differ (16).There are limitations on the literature reviews or previous studies.

One of the limitation is that; Car drivers maintain longer headways when following trucks than cars (11). But without undertaking the condition of the road and air condition it is difficult to conclude as such. Another fundamental limitation is that while the PCE measures the overall delay created by trucks it does not account for their separate effects on cars and trucks. These effects are not yet well understood (11).

In addition to the above gaps; delay created by a vehicle may depend on the composition of vehicles in the traffic stream (9) . Some studies have found that the PCE of trucks is an increasing function of the fraction of trucks (26). Vissim is the leading microscopic simulation program for modeling multimodal transport operations and belongs to the Vision Traffic Suite software. Realistic and accurate in every

detail, vissim creates the best conditions for you to test different traffic scenarios before their realization (28).

2.2. Operational definitions

2.2.1 Performance

Performance is combination of Level of service of the road, Safety, mobility (travel time or speed) and reliability (consistency of travel time or speed) (17).

Single-unit trucks (Includes two-axle, four-tire trucks and other single unit trucks i.e. - it does not carry its cargo in an attached trailer).

Passenger car equivalent (PCE) factors those are vital as they provide mechanism through which vehicles are converted into reference vehicle (i.e. Car).

2.2.1.1 Safety: Crash frequency and conflict points

Crashes: many different terms are commonly used to describe vehicle collisions. The world health organization use the term road traffic injure, while the U.S. Census Bureau uses the term motor vehicle Crushes (MVC),and transport Canada uses the term "motor vehicle traffic collision" (MVTC).Other terms that are commonly used include auto accident, car accident, car crash, car smash, car wreck, personal injury collision (PIC), road accident, road traffic accident (RTA), road traffic collision (RTC), road traffic incident (RTI), road traffic accident and later road traffic collision, as well as more unofficial terms including smash-up, pile-up, and fender bender**.** Therefore these all are definition of the crash.

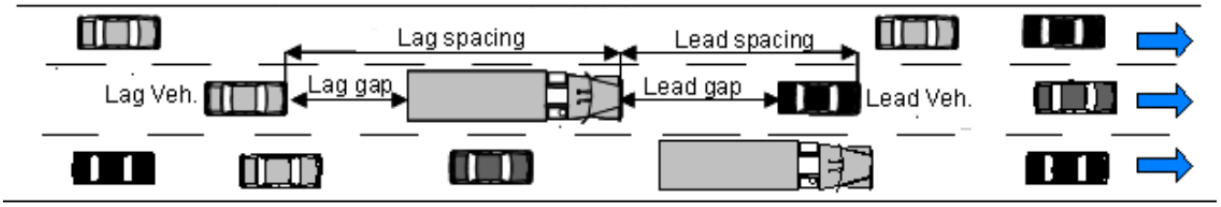


Figure 3: One direction flow of vehicles (source: Australasian Transport Research Forum 2011)

2.2.1.2 Mobility – Average travel time

Mobility is average travel time (speed) of all vehicles using the same road sections.

Travel time- The average time spent by vehicles traversing a highway segment (300m) within uninterrupted section; it is from site collected parameter and 80km/hr is posted speed on all midblock ring roads.

2.2.1.3 Reliability – Reliability is consistency in travel time; that means whether travel time (speed) of different vehicles is almost the same or very different from other vehicles speed.

Travel Time Reliability: By its very nature, roadway performance is at the same time consistent and repetitive and yet highly variable and unpredictable. It is consistent and repetitive in that peak usage periods occur regularly and can be predicted with a high degree of reliability. (The relative size and timing of "rush hour" is well known in most communities.) At the same time, it is highly variable and unpredictable, in that on any given day, unusual circumstances such as crashes can dramatically change the performance of the roadway, affecting both travel speeds and throughput volumes (27).

Delay: assuming that all the vehicles complete their trips expressed by the sum of time lost due to congestion. From the standard of Addis Ababa ring roads, those vehicles with travel speed of 80km/hr will arrive at their destination without delay and those vehicles with speed less than 80km/hr will be classified under delayed cars (27).

Traffic congestion is a condition on road networks that occurs as use increases, and is characterized by slower speeds, longer trip times, and increased vehicular queuing. The most common example is the physical use of roads by vehicles. When traffic demand is great enough, that the interaction between vehicles slows the speed of the traffic stream, this results in some congestion (27).

Traffic congestion occurs when a volume of traffic or modal split generates demand for space greater than the available road capacity; this point is commonly termed as saturation.

The entry of heavy vehicles that is, vehicles other than passenger cars (a category that includes light trucks and vans) into the traffic stream affects the number of vehicles that can be served. Heavy vehicles are vehicles that have more than four tires touching the pavement (17). Therefore, traffic congestion increase as number of heavy vehicles using same lane with the light vehicles increase.

Truck-Car (heavy-Light vehicles) interaction and Car-Car (Light-Light vehicles) interaction:

The key terminologies and variables used in this study to describe the interactions during light vehicles following a heavy vehicle shown in Figure 2. Important insights to the impact of vehicle interactions can be obtained by investigating the fundamental traffic flow characteristics such as site data collection.

Heavy vehicle is a vehicle with greater than four tyre touching the pavement and light vehicle is a vehicle with four tyre touching the pavement. In this paper car is taken as light vehicle and truck is heavy vehicle.

2.2.1.4. Quality of Service

Level of Service: it is quality of operations (traffic flow) on a facility with defined traffic, roadway, and control conditions. It is the main impact and will occur during common lane usage.

The ideal average interchange or roundabout spacing on freeway is greater than 2 mi and Arterial Street is with signal or roundabout spacing of 2.0 mi or less(17).

Arterial Street LOS is based on average through vehicle travel speed for the segment or section under consideration; The following general statements characterize LOS along urban streets(17)

LOS A describes primarily free-flow operations at average travel speeds, usually about 90 percent of the FFS for the given street class.

LOS B describes reasonably unimpeded operations at average travel speeds, usually about 70 percent of the FFS for the street class.

LOS C describes stable operations; however, ability to maneuver and change lanes in midblock locations may be more restricted than at LOS B, and longer queues, adverse signal coordination, or both may contribute to lower average travel speeds of about 50 percent of the FFS for the street class.

LOS D borders on a range in which small increases in flow may cause substantial increases in delay and decreases in travel speed. LOS D may be due to adverse signal progression, inappropriate signal timing, high volumes, or a combination of these factors. Average travel speeds are about 40 percent of FFS.

LOS E is characterized by significant delays and average travel speeds of 33 percent or less of the FFS. Such operations are caused by a combination of adverse progression, high signal density, high volumes, extensive delays at critical intersections, and inappropriate signal timing.

LOS F is characterized by urban street flow at extremely low speeds, typically one-third to one-fourth of the FFS. Intersection congestion is likely at critical signalized locations, with high delays, high volumes, and extensive queuing. Addis Ababa ring roads posted speed is different for frontage and midblock lanes.

Accordingly posted speed for frontage lanes is 50km/hr and posted (free flow) speed for midblock lanes is 80km/hr. Depending on the above category, Addis Ababa midblock ring roads level of service classification is as follow:

LOS A describes primarily free-flow operations at average travel speeds, which is greater than or equal to 72km/hr for the given street section.

LOS B describes reasonably unimpeded operations at average travel speeds, which is greater than or equal to 56km/hr but less than 72km/hr for the given street section.

LOS C describes stable operations; however, ability to maneuver and change lanes in midblock locations may be more restricted than at LOS B, and longer queues, lower average travel speeds which is greater than or equal to 40km/hr but less than 56km/hr for the given street section.

LOS D borders on a range in which small increases in flow may cause substantial increases in delay and decreases in travel speed, which is greater than or equal to 32km/hr but less than 40km/hr for the given street section.

LOS E is characterized by significant delays and very low average travel speeds, which is greater than or equal to 27km/hr but less than 32km/hr for the given street section.

LOS F is characterized by urban street flow at extremely low speeds, which is less than or equal to 27km/hr for the given street section; with high delays, high volumes, and extensive queuing.

CHAPTER THREE

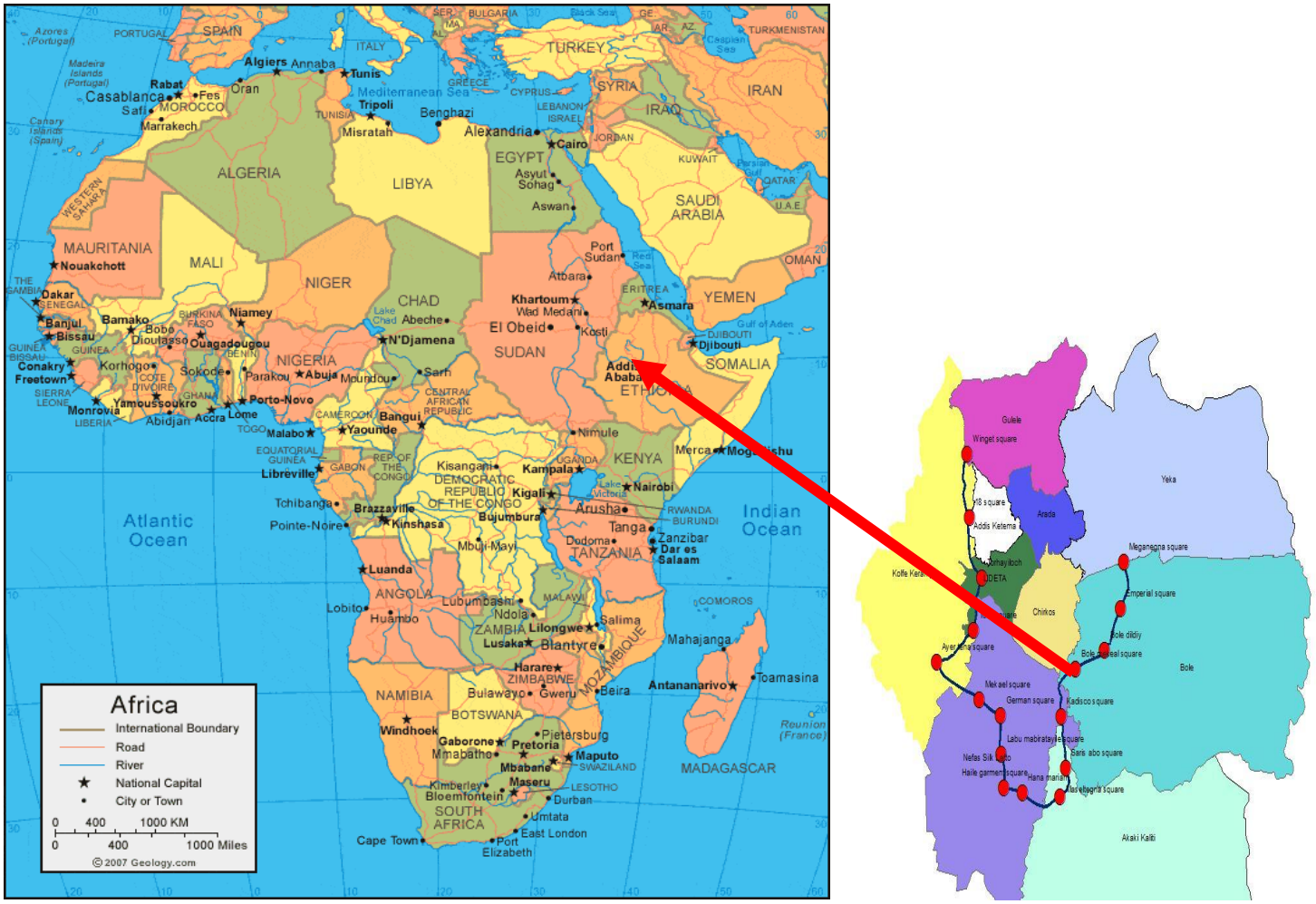
METHODOLOGY

3.1 STUDY AREA AND PERIOD

The 11 Addis Ababa ring road segments used for this study were; Winget-18 RA (2.7km), 18 RA-Torhayloch (2.66km), Torhayloch-Total RA (2.17km), Ayer tena RA-Mikeal RA (3.2km), Mikeal RA-German RA (1.36km), German RA-LebumebrathayleRA (1.79km), Hanamariam-Maseltegna (2.47km), Saris Abo RA –kadisco RA(2.12km), Kadisco RA-Bole Mikeal RA(2.5km), Bole dildiy(airport)-Emperial RA (1.9km) and Emperial RA-Megenagna (2.1km) road sections. Qualitative data (both self administered questionnaire and secondary data) were collected and interview of second person is also included.

But for quantitative data (video) the design is from actual vehicles movement capture to fill the format.

This study was conducted from 21st September, 2016 to 2nd January, 2017 G.C in Addis Ababa. In the data collected there was no at night collected traffic data. All collected data were during day only.


Africa
International Boundary
Road
River
National Capital
City or Town
0 400 1000 KM
0 400 1000 Miles
© 2007 Geology.com
Atlantic Ocean
Indian Ocean
Mediterranean Sea
Red Sea
Persian Gulf
Gulf of Aden
Black Sea
Caspian Sea
Lake Victoria
Lake Chad
Algiers
Annaba
Tunis
Rabat
Casablanca
Fes
Oran
Safi
Marrakech
Tripoli
Misratah
Benghazi
Alexandria
Cairo
Asyut
Sohag
Aswan
Port Sudan
Atbara
Khartoum
Wad Medani
El Obeid
Kosti
Abeche
N'Djamena
Asmara
Djibouti
Addis Ababa
Nimule
Kisangani
Kampala
Nairobi
Kigali
Arusha
Tanga
Zanzibar
Dar es Salaam
Dodoma
Bujumbura
Kinshasa
Brazzaville
Pointe-Noire
Tchibanga
Libreville
Malabo
Yaounde
Bangui
Mbuji-Mayi
Luanda
Lubumbashi
Ndola
Lilongwe
Lusaka
Blantyre
Salima
Lobito
Huambo
Harare
Bulawayo
Gweru
Beira
Mahajanga
Antananarivo
Toamasina
Windhoek
Gaborone
Mmabatho
Pretoria
Pietersburg
Maputo
Mbabane
Maseru
Kimberley
Bloemfontein
Durban
Umtata
East London
Port Elizabeth
Cape Town
Merca
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Yemen
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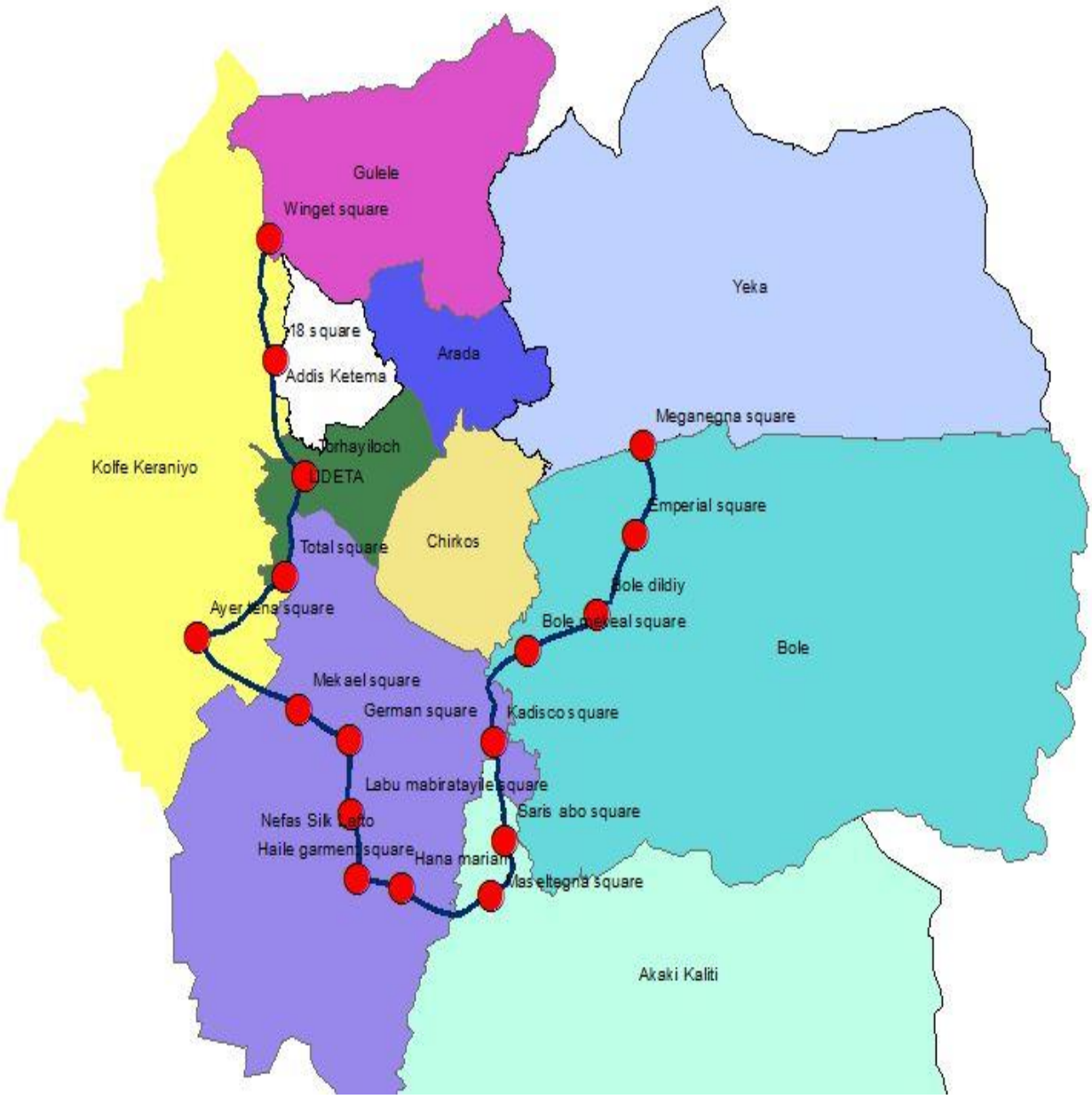
Iran
Iraq
Syria
Turkey
Egypt
Libya
Algeria
Mauritania
Mali
Niger
Nigeria
Chad
Sudan
Somalia
Ethiopia
Kenya
Uganda
Rwanda
Burundi
Tanzania
Zambia
Angola
Malawi
Mozambique
Zimbabwe
Namibia
Botswana
South Africa
Swaziland
Lesotho
Madagascar
Comoros
Reunion (France)
Nouakchott
Dakar
Banjul
Bissau
Bamako
Conakry
Freetown
Monrovia
Abidjan
Accra
Lome
Porto-Novo
Abuja
Parakou
Niamey
Ouagadougou
Korhogo
Sokode
Yamoussoukro
Mundou
Sarh
Oman
United Arab Emirates
Qatar
Kuwait
Jordan
Lebanon
Israel
Cyprus
Greece
Bulgaria
Italy
Portugal
Spain
Turkmenistan
Gulele
Winget square
Yeka
Arada
Addis Ketema
Meganegna square
Kolfe Keran
Chirkos
Emperial square
Bole
Mekael square
German square
Kadisco square
Nefas Silk Lafto
Haile garment square
Akaki Kaliti



Legend:

- Ring road line
- Roundabout or Signalized intersection

Figure 4: Location of Ring road

3.2. DATA COLLECTION

In order to study the car-following behavior or same lane usage, traffic survey were performed on 11 road sections by four data collectors. During pilot study the effect of traffic congestion at roundabout was seen at 500m far from roundabout and from the selected 11 road sections the shortest section is 1.36km, therefore the length of each road segment section on which the data were collected is 300m.The portion of the urban street being analyzed should be at least 1 mile long in a downtown area and 2 mi long elsewhere for the LOS speed criteria to be meaningful. Study lengths shorter than 1 mi should be analyzed as individual intersections and the LOS assessed according to individual intersection criteria (17).

Length of time to collect data is 15minute; because traffic does not flow evenly over an hour, sub hourly peaking should be accounted for when the analysis is in terms of other than 15 min flows (17).

Mounting several video cameras on the top of the buildings on the ways of road section provide more accurate data than using one camera and manual counting. But because of inappropriateness of the section of roads to do this and economic point of view, the researcher prefer to collect the data from one point with high standard video camera. Secondary data (vehicle collision types) for safety was collected from Addis Ababa police commission.

For other variables affecting performance of the ring roads self administered questionnaires (principal investigator interviewed the drivers) were prepared.

Daily laborers took the meter and marking colors during measurement, point markers mark the initial and the end points and the data collectors adjust the data collecting instruments and give information by standing on the marked points. Finally the principal investigator collects data by the selected instrument.

Vehicles crash inspectors participated in the secondary data collection by providing vehicle to vehicle crash data from each sub city police stations.

In the data collection by questionnaires, principal investigator interviewed the drivers of both heavy and light vehicles and fill on the prepared format.

3.2.1 Specific data collected

Data collected for performance analyses were: occurrence of vehicle-vehicle collision with specific ring road location, actual travel speed with type of vehicle and travel time during light vehicle following light vehicle, light vehicle following heavy vehicle using video camera and self administered questionnaire was used to collect information related to geometry of the road.

3.2.3. List of materials and tools used

Camera: Canon with view angle 170^{o}, 18.5 MP (mega pixel), Movie type (Video H.264, sound: linear PCM, recording level can be manually adjusted by user) and storage type of; SD, SDHC (UHS-I) card.

This instrument was used to collected vehicles flow within the selected 300m road section on each segment.

Tape Measure: Flexible tape measure with 100m length and marked both in inch and meter. This tool was used to measure 300m long section of road on which video data were collected.

Paints: Nifas silk paint with white color and used to mark initial, intermediate and final points of readings.

3.3 METHODOLOGY FOR DATA COLLECTION

For performance analysis data collection **(Video Data)**, first two points on a road section were selected and marked. Before any vehicle inter to the selected section the video camera made on. From the video the time at which the front bumper of the vehicle touches the first marked point and the time at which that vehicle back bumper arrives at the second marked point were recorded on the prepared printout data sheet; (**APPENDEX G:** the format of the datasheet). These temporal data (1056) were collected for two vehicle flow combinations: Light-Heavy vehicle (L-H; 528) and Light-Light vehicle (L-L; 528). Three scenarios (Scenario 1: Light vehicles following light vehicles **(removing heavy vehicles from ring roads)**; removing all heavy vehicles Scenario 2: light vehicles with heavy vehicles **(lane restriction)**; restricting light vehicles to the inner of midblock ring rod and heavy vehicles limited to the outer lane of the midblock ring road and Scenario 3: light vehicles following heavy vehicles **(common lane utilization)**; both type of vehicles (light and heavy vehicles) use common lane) were developed to compare the difference between different vehicle combinations.

Slope of the road segment where considered by taking initial and end of segments elevation using hand GPS and taking 300m segment length and two points elevation difference; slope of the road segment has been calculated.

Effect of slope on road performance was analyzed using the following hypothesis.

Hypothesis:

H0: The mean speed of down, up and flat are the same

H1: At least the mean of one slope is different from the other

Level of service was obtained using percentage posted speed, as stated in operational definition and compared with actual speed of the vehicles.

To obtain effect of segments difference on speed Using front vehicles speed without considering other parameters (vehicles combination, pavement condition and slope) has been done using the following two hypotheses.

Effect of segments on speed of front vehicles

Hypothesis:

H0: The mean speed of front vehicles at each segment is equal

H1: The mean speed is different at least in one segment

Figure 5: A typical digital camera setup on pedestrian over cross

For performance analysis (specifically to analysis impact road condition on road performance) data collection **(questionnaire data)**, Closed and structured questionnaire were prepared. Questionnaires were prepared in English, translated in to Amharic during in depth interview.

For performance analysis data collection **(secondary data),** a tabular format, (**APPENDEX F**), was prepared by investigator and distributed to three Addis Ababa community police stations. Those three sub cities (konlfe keraniyo,Nifas silk lafto and Bole) are the sub city where the ring road segments are located.

3.4 SAMPLE SIZE DETERMINATION

3.4.1. Sample size determination for qualitative (questionnaire)

The sample size for qualitative study was determined based up on the point of saturation (no change to respondent's answer). After questionnaires were prepared the self administered questionnaire were answered by participants. But after around 190 participants gives response the response becomes redundant and attain saturation (no change to respondent's answer) criteria & 202 participants had responded the questionnaire.

All road sections selected for data collection were ring roads (mid block); because frontages ring road performance is sometimes affected by on-street parking. Generally there are 18 ring road segments in Addis Ababa but 11 of them were selected; Due to appropriateness of segments to collect data and availability of both midblock and frontage ring road part separately.

Those selected road sections were; Winget-18 RA (2.7km), 18 RA-Torhayloch (2.66km), Torhayloch-Total RA (2.17km), Ayer tena RA-Mikeal RA (3.2km), Mikeal RA-German RA (1.36km), German RA-Lebumebrathayle RA (1.79km), Hanamariam-Maseltegna (2.47km), Saris Abo RA –kadisco RA (2.12km), Kadisco RA-Bole Mikeal RA (2.5km), Bole dildiy(airport)-Emperial RA (1.9km) and Emperial RA-Megenagna (2.1km).

Mechanisms, such as the controlled intersection and Midblock on ring roads are used to maximize flow along the system. But in Addis Ababa those stations are highly congested. Therefore to ignore impacts on speed of moving vehicles by congestion and normal driving speed interference on midblock of ring roads, the data collection was started at minimum of 500m away from roundabout.

3.4.2. Sample size determination for Vehicle-Vehicle crash data

Again the sample size for this qualitative data was determined based up on the point of saturation (redundancy). After format for data collection was prepared and distributed to three sub city police stations and the prepared format has filled or answered sub city's police station experts. But after around 95 Vehicle-Vehicle crash recorded the response becomes redundant and attains saturation criteria & 104 Vehicle-Vehicle crash has been recorded.

3.4.3. Sample size determination for quantitative (video data)

Sample size of video data for vehicle-vehicle flow combination arrangements was decided using standard techniques. The following formula was applied to decide the size of this sample.

Using statistical sample size calculation; first 20 samples were recorded as pilot study and for this sample size standard deviation is calculated by the formula:

$$S = \sqrt{\frac{\sum(X - X')2}{n - 1}}$$

Where X=individual mean

X'=sample mean and

n=pilot sample size

S=0.683

Using this standard deviation; sample size was determined approximately 1056 by the formula;

$$n = \frac{(Z_{\frac{\alpha}{2}} * \delta)^2}{(E)^2}$$

Where E is maximum error of estimate which ranges (1-5%), n= sample size, $Z_{\frac{\alpha}{2}}$ =1.96 for 95% level of confidence and δ =0.683 is calculated standard deviation.

3.5 VARIABLES (PARAMETERS) OF THE STUDY

Dependent variables (a variable which can be affected by another variable)		
✓ Speed of vehicles – affected (differ) by vehicles combination (H-L and L-L) and other variables ✓ Level of Service(LOS) - affected (differ) by vehicles combination (H-L and L-L) and other variables		
Independent variables (a variable which can't be affected by another variable)		
❖ **Follow combination of vehicles**		
✓ Light vehicle follow Light vehicle(LL)	✓ Light vehicle follow Heavy vehicle (LH)	
❖ **Section of the road (Road Segment)**		
✓ Winget-18 RA	✓ German RA-Lebu mebrat RA	✓ Emperial RA-Megenagna RA
✓ 18 RA –Torhayloch	✓ Hanna mariam-Maseltegna	
✓ Torhayloch –Total	✓ Saris abo RA-Kadisco RA	

✓ Ayertena RA-Mikeal RA	✓ Kadisco RA-Bole mikeal RA	
✓ Mikeal RA-German RA	✓ Bole Dildiy-Emperial RA	
❖ **Slope of the road section(segment)**		
✓ Up (positive grade)	✓ Down (Negative grade)	✓ Flat
❖ **Road Surface Condition**		

3.6. DATA ANALYSIS

Data was entered in to SPSS (Statistical Package for Social science) version 20.0 for analysis, then after cleaned and coded. To avoid errors, data was entered by two separate persons and the consistency between two entered data was checked. Both descriptive and inferential statistics were used. For descriptive part different statistical figures (mean, proportion, variance and standard deviation) and for inferential statistics different statistical tests (T- test, F-test and chi square) were used. This all analysis is to compare performance of the Addis Ababa ring road when light follow heavy vehicle and light vehicle follow light vehicle.

Both independent T-test and Analysis of variance (ANOVA) were used to see the real effect of common lane utilization on performance of the ring road.

Analysis of variance (ANOVA) was used to test the equality of mean speed of different vehicles in different conditions. Since ANOVA gives only whether at least one of the mean is different from the other, once after at least one mean is different from the other, post hoc test was conduct to check whether the difference is exist between each mean.

Another data analysis method used was VISSIM 9 software. Aggregated data (vehicles speed, vehicles types and combinations of vehicles; Light-Light vehicle and Heavy-Light vehicles combinations were entered into the software. The software gives simulation of different vehicles combination and it compares property of different vehicle combination simulation.

CHAPTER FOUR

RESULT AND ANALYSIS

4.1. CAUSES OF DECREASE IN PERFORMANCE OF THE RING ROAD

All of the 202 respondents were considered for analysis. Out of 202 respondents about 50% of them were drivers of vehicles with four tyres and the rest 50% were drivers of vehicles with more than four tyres. Majority of the respondent uses the ring road with speed less than posted speed. From this, 27.7% of the respondents were used 50-60km/hr and 27.7% of the respondents were used 60-70km/hr and only 16.8% respondents were used speed beyond posted speed (80km/hr). The rest 24.8% respondents were used almost equal to posted speed which is greater than 70km/hr but less than or equal to 80km/hr. Most of the vehicles (80.7%) following slowly moving light vehicle have decided to change their lane freely or follow by decreasing speed but 80.7% of vehicles following slowly moving heavy vehicles have decided to change their lane uncomfortably or follow by decreasing speed. Both horizontal and vertical curve have moderate impacts on all vehicles. From the total of 202 following heavy vehicles 60.4% of all vehicles faced sight distance problem, felt discomfort and enforced to change lane. But out of all vehicles following light vehicles, 91.6% of them only enforced to change lane.

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4.1.1. Impact of heavy vehicles on performance of the road

From collected data during free of congestion majority of the heavy vehicles speed is between 60km/hr to 50km/hr and majority of light vehicles speed is 70 to 80km/hr; figure B-1. This shows that speed of heavy vehicle is much less than speeds of light vehicle. That means decreasing speed of vehicles is also decreasing in level of service of the road.

Concerning mobility or travel time, most of heavy vehicles 46 vehicles (45.54%)used average speed of 50-60km/hr and 40 light vehicles (39.6%) used the average speed of 70-80km/hr. when reliability is analyzed there is inconsistency in speed. From total of 202 vehicles, (41.6%) of total vehicles used ≥70 km/hr and (30.7%) of total vehicles used ≤ 60km/hr which shows inconsistent.

Out of 101 light vehicles only 10 (9.9%) light vehicles use speed less than 60km/hr and 67 (66.3%) light vehicles use greater than 70km/hr but from total of 101 heavy vehicles only 17 (16.8%) vehicles use the speed greater 70km/hr. This shows when heavy and light vehicles use common lane, the speed of vehicles becomes inconsistency and the average speed also decreased, and this affects level of service of the road.

4.1.2. Impact of Light vehicle following heavy vehicle and vice versa on performance of the road

4.1.2.1 All Vehicles following slowly moving light vehicle

In this case any vehicles are follower & slowly moving light vehicle is front or leading vehicle.

Decisions of any vehicles following slowly moving light vehicle

Out of 202 vehicles following slowly moving light vehicle 163 of them change lane freely or follow by decreasing speed and the rest of them change lane uncomfortably or only follow by decreasing speed. This means, almost all vehicles follow or change lane freely when following slowly moving light vehicles.

In percentage form; 80.69% of all vehicles following slowly moving light vehicle freely change the lane or follow by decreasing speed. But only 14.85% of all vehicles following slowly moving light vehicle change lane uncomfortably or follow by decreasing speed and 0.5% of vehicles decide only following by decreasing speed. Therefore slowly moving light vehicles being leading doesn't significantly affect speed of any vehicles.

Problems encountered following slowly moving light vehicle

Out of 202 vehicles following slowly moving light vehicles only 16 vehicles were discomforted and change lane but 185 vehicles (92%) were only enforced to change lane. This shows that following slowly moving vehicle is not significant causes for safety problem (discomfort).

Generally, 92% of vehicles following slowly moving light vehicle only enforced to change lane and only 8% of total vehicles following slowly moving light vehicles feel discomfort & enforced to change lane. But out of all light vehicles only 2% of them felt discomfort following slowly moving light vehicle. From this; following slowly moving light vehicle only enforce to change lane and have no significant impact on speed and safety.

Comfortable positions for lagging vehicles if can't overtake slowly moving light vehicle

If the lagging vehicle can't overtake the leading vehicle the appropriate position for lagging vehicle is different for heavy and light vehicles. From 202 vehicles following slowly moving light vehicles 165 vehicles or 81% (79 heavy and 86 light vehicles) prefers both side to side using adjacent lane & following by decreasing speed and 32 vehicles or 15.8% (20 heavy and 12 light vehicles) prefers only side to side using adjacent lane and the rest 5 vehicles or 2.5% (2 heavy and 3 light vehicles) selects only following by decreasing speed. In this case equal number of heavy and light vehicles prefers all options equally.

Since small number of lagging vehicles (2.5%) and only 15.8%of vehicles prefer only following by decreasing speed & prefer side to side using adjacent lane respectively; all vehicles freely follow or move side to side with slowly moving light vehicles.

4.1.2.2. All Vehicles following heavy Vehicle

In this case any vehicles are follower or lagging vehicle & Heavy vehicle is front or leading vehicle and this heavy vehicle is the slowly moving vehicle.

Decisions of any vehicles following slowly moving heavy vehicle

In car following behavior; out 202 v**e**hicles following slowly moving heavy vehicle 163 of them change lane uncomfortably or follow by decreasing speed ,8 of them only decide changing lane uncomfortably without decreasing speed and 29 of them change lane freely or follow by decreasing speed. But out of 29 vehicles decided to change lane freely 23 of them are heavy vehicles.

High number of light vehicles following slowly moving heavy vehicles change lane uncomfortably and follow by decreasing speed if there is no another options. In percentage form; 80.7% of all vehicles following slowly moving heavy vehicle change lane uncomfortably or follow by decreasing speed and 0.5% of vehicles decide only following by decreasing speed.

Therefore slowly moving heavy vehicles being leading significantly affect speed of any vehicles and safety than following slowly moving light vehicles.

Problems encountered following slowly moving heavy vehicle

From all 202 participants following heavy vehicles; 93 light vehicles faced sight distance problem, discomfort and enforced to change lane. But only 29 heavy vehicles faced those problems (sight distance problem, discomfort and enforced to change lane). That means almost all of light vehicles have faced sight distance problem, discomfort and enforced to change lane. Generally 92.1% of light vehicles following slowly moving heavy vehicle have faced sight distance problem, discomfort and enforced to change lane. But only 28.7% of heavy vehicles have faced these all problems listed above. From this; there is significant safety problems and speed reduction if light vehicles follow slowly moving heavy vehicle than heavy vehicles following slowly moving heavy vehicle.

Comfortable positions for lagging vehicles if can't overtake slowly moving heavy vehicle

Out of 202 vehicles following slowly moving heavy vehicles 175 vehicles or 86.6% (76 heavy and 99 light vehicles) prefers side to side using adjacent lane only and 23 vehicles or 11.38% (23 heavy and no light vehicles) prefers both side to side using adjacent lane & follow by decreasing speed and the rest 4 vehicles or 2% (2 heavy and 2 light vehicles) selects only following by decreasing speed. Since high number of vehicles (86.6%) (76 heavy and 99 light vehicles) prefer only side to side and only 2% of vehicles prefer only following by decreasing speed; there is safety problem if vehicles follow slowly moving heavy vehicles.

4.1.3. Impact of road geometry on performance of the road

Out of 202 participants almost speed of all of them affected by horizontal curve and vertical curve (grade) of the road that means about 199 of them affected by those causes.

4.1.3.1 Horizontal curve

From the result of participant response speed of heavy vehicles were affected than light vehicles by presence of horizontal curve on Addis Ababa ring roads, and heavy vehicles were affected severely; that means all of heavy and 98 light vehicles speed were affected by horizontal curve.

From the analysis horizontal curves on Addis Ababa ring roads moderately affect speed of light and heavy vehicles which are 85% of heavy vehicles and 94% of light vehicles were affected. Therefore presence of horizontal curve moderately affects performance of road.

4.1.3.2 Vertical Curve

From the result of participant response speed of heavy vehicles were affected than light vehicles by presence of vertical curve(Grade) on Addis Ababa ring roads, and heavy vehicles were affected severely; that means 101 heavy and 98 light vehicles speed were affected by Vertical curve, and 16 Light and 23 heavy vehicles were affected highly.

This shows that; vertical curves on Addis Ababa ring roads moderately affect speed of light and heavy vehicles equally which is 76 (75%) of heavy vehicles and 80 (81%) of light vehicles. Therefore presence of vertical curve moderately affects performance of road.

4.1.4. Impact of Pavement condition on road performance

Out of 202 participant response speed of heavy vehicles and light vehicles were affected almost equally by road condition (defects) on Addis Ababa ring roads; that means 100 heavy and 99 light vehicles speed were affected by road condition (defects), and 50 Light and 23 heavy vehicles were affected highly. From output below both light vehicles and heavy vehicles are equally affected to the moderate & high extent. Speed of About 46.5% of heavy vehicles and 50.5% of light vehicles highly affected; which means both vehicles categories were almost equally affected by pavement condition problems and Speed of 53.3% heavy vehicles and 49.5% light vehicles were moderately affected by surface condition problems. This shows that performance of road was affected because of road surface condition problem than geometry of the road.

4.2. VEHICLE-VEHICLE CONFLICT

4.2.1. Vehicle-Vehicle conflict location (sub city)

Out of 104 Vehicle-Vehicle conflicts happened on Addia Ababa midblock ring roads 28.8% is in Nefas silk lafto subcity, 44.2% is in kolfekeraniyo and 26.9% is in Bole sub city.

4.2.2 Reasons of Vehicle-Vehicle Conflict

Out of six main causes (reasons) of crash (illegally using opposite lane, no enough headway, illegal overtake, unacceptable driving backward, illegal lane change and vehicle out of control) about 17.3% is a conflict between heavy - light vehicle and 8.7% is between Light-light vehicles because of less headway (no enough headway) and 24% of conflict is between light–light vehicles and 13.5% is between heavy-light because of illegal lane change and because of illegal overtake is 9.6% occurred between light-light vehicles.

Generally conflict or crash made between Heavy –Light, Light-Light and Heavy-Heavy because of unacceptable driving back were 5.8%, 1.9% and 1.9% respectively. A crash occurred between Heavy-Light vehicle because of illegally using opposite lane, illegal overtake and vehicles out of control were 1%, 5.8% and 2.9%.A Heavy- Heavy crash made because of no enough headway, illegal lane change, illegal overtake and unacceptable driving back were 1.9%, 2.9%, 2.9% and 1.9%. From this result out of light- light vehicles crash happened ;24% of it was happened because of illegal lane change which means when the front vehicles slowly move or if the followers are discomforted by following front vehicle it prefer to change lane rather than following, which result in light-light vehicle conflict. The second highest conflict percent happened was Heavy-light vehicles conflict which is 17.3% because of no enough headway. Therefore one of the road performance parameter which is safety is affected by light vehicle with light vehicle conflict because of illegal lane change. This illegal lane change is because of; sight distance problem if the leading vehicle is heavy and discomfort if the leading vehicles is heavy.

4.3. VIDEO DATA RESULT FOR PERFORMANCE ANALYSIS

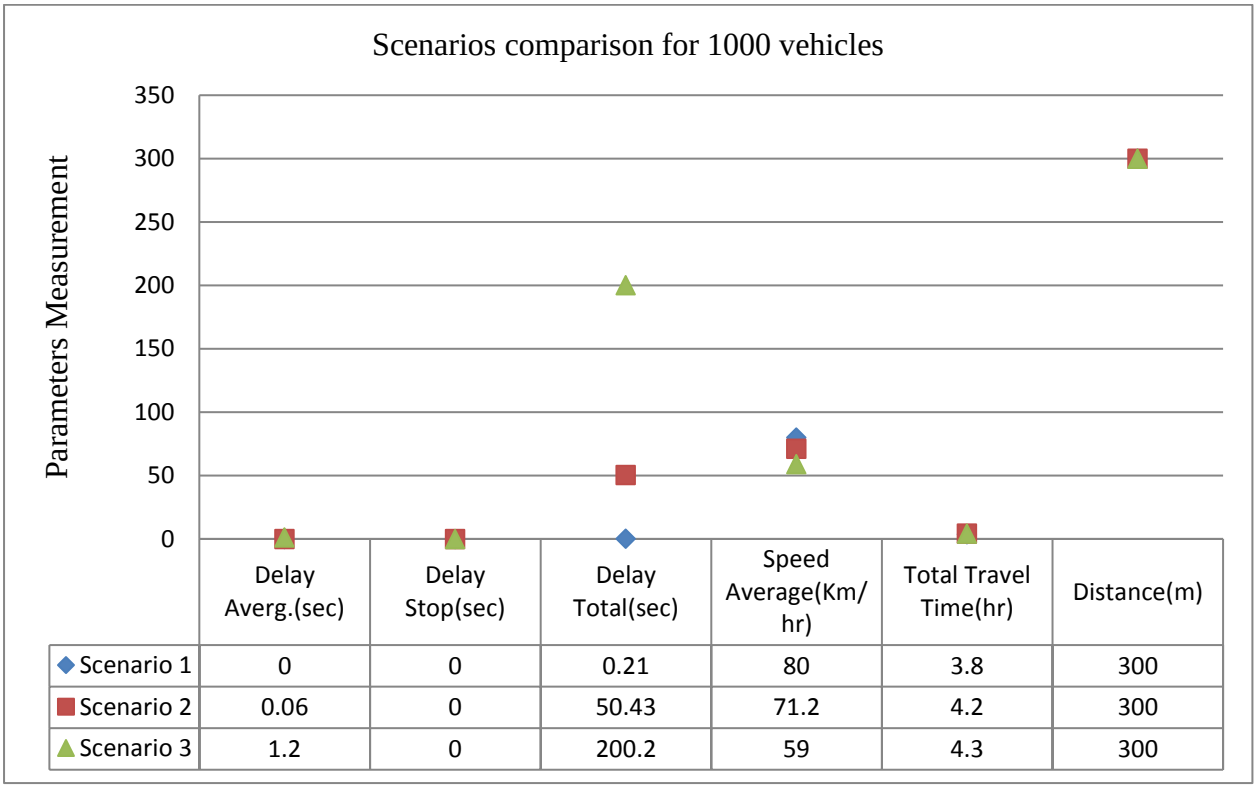
4.3.1 Impact of car following behavior on performance of the midblock ring road

From vissim 9 output three Scenarios have been done:

Scenario 1: Light vehicles following light vehicles **(removing heavy vehicles from ring roads)**; removing all heavy vehicles and assigning all heavy vehicles to another outer ring road which will be constructed in the future.

Scenario 2: light vehicles with heavy vehicles **(lane restriction)**; restricting light vehicles to the inner of midblock ring rod and heavy vehicles limited to the outer lane of the midblock ring road.

Scenario 3: light vehicles following heavy vehicles **(common lane utilization)**; both type of vehicles (light and heavy vehicles) use common lane.



	Delay Averg.(sec)	Delay Stop(sec)	Delay Total(sec)	Speed Average(Km/ hr)	Total Travel Time(hr)	Distance(m)
Scenario 1	0	0	0.21	80	3.8	300
Scenario 2	0.06	0	50.43	71.2	4.2	300
Scenario 3	1.2	0	200.2	59	4.3	300

Graph 1: The Three Scenarios Comparison

In scenario 1 there is no average delay and 0.21 sec. total delay but in scenario 2 average delay is 0.06sec, and 50.43 sec total delay and in scenario 3 1.2sec average delay and 200.2 sec total delay.

From these, when light and heavy vehicles utilize the same lane; average and total delay is higher than other combination (other scenarios) which shows performance decrease.

Concerning travel time; to cover 300m long road section if only light vehicles are using that road, 1000 light vehicles will cover 300m long road within 3.8hr but if lane restriction was applied 1000 light and heavy vehicles will cover 300m long road within 4.2hr using different lane and if both light and heavy vehicles are utilizing common lane 1000 light and heavy vehicles will cover 302m long road within 4.3hr.from this travel time for all of the scenario is different and travel time for common lane utilization option is long; therefore performance of the midblock ring road was affected because of the common lane utilization of light and heavy vehicles.

4.3.1. Impact of slope of the segment on Performance of the road

Out of 1056 car following behavior vehicles collected on study area; on positive grade (up) 40.9% vehicles, on negative grade (down) 40.9% vehicles and the rest 18.2% vehicles were on flat terrain.

From the analysis, Out of 1056 participants 432 vehicles were collected on upgrade, 432 vehicles were on down grade and the rest 192vehicles were on flat slope.

From the analysis result (ANOVA) mean speed difference between different slopes is not significant which is 0.436 > 0.05.

Table 1: Front Vehicle Mean Speed difference Significance

Speed of front vehicle (km/hr)					
Groups	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1471.803	2	735.901	.831	.436
Within Groups	932511.011	1053	885.576		
Total	933982.813	1055			

The finding indicated that, the speed of vehicle at each slope is the same; this implies that there is no significant (P=0.436>0.05) mean difference among different slopes.

Using Post Hoc Test significance of mean speed of front vehicles among each slope types is show below.

All slopes (Positive grade, negative grade and flat) mean speeds are almost the same which means, difference in mean speed is insignificant.

Accordingly significance level or P value of positive grade in relation with down grade and flat is 0.332 and 0.246 respectively, which are greater than 0.05. In the same manner all P values are greater

than 0.05 which shows speed of front vehicles are not significantly different on Addis Ababa positive grade, negative grade and flat ring road segments.

From the crosstabs and chi-square analysis output; the difference in level of service of the road on flat, up and down grade is not significant (P-Value=0.091 which is greater than 0.05); see Table E-3

4.3.2. Impact of heavy-light vehicles and light-light vehicles combination on road performance

In car following behavior the mean speed of rear vehicles when light vehicles following heavy vehicle is 67.6km/hr and 80.8km/hr when light follow light vehicles.

Using independent T-test significance of mean speed difference of light-heavy and light-light combination is less than 0.001 which is highly significant. This shows when heavy vehicle is front, speed of rear vehicles highly affected.

From independent T test Mean Speed of rear vehicle when light follow heavy vehicle is 67.6 km/hr and when light follows light vehicle mean speed of rear vehicle is 80.8 km/hr.

In both combinations (heavy-light vehicle and light-light vehicle) the lagging or rear vehicles is light vehicle, but from result below in heavy-light vehicle combination 53.6% of light vehicles have speed of Level of service A and 73.5% of light vehicles have speed of level of service A.

This shows that speed of light vehicles following heavy vehicles hindered by presence of heavy vehicle. From chi-square result difference of level of service of road on which heavy – light vehicles combination is significant when seen with the level of service of road on which light-light vehicles combination exist (P-value of less than 0.001 which is highly significant).

4.3.3. Difference in road performance for different segments

The speed of front vehicle in car following behavior also different for different road segments without considering other cases which hinder the speed of vehicles.

From all 11segments studied Ayer tena RA– Mikeal RA have mean speed 82.8km/hr which is the highest of all and winget-18 RA have 50.9km/hr which is the lowest of all.

Road surface condition of the Winget -18 RA segment is not good. E.g. Existence of speed brakers that is why on Winget -18 RA road speeds of vehicles becomes light(50.9km/hr) and speed of vehicles on Ayertena-Mechael RA segment is higher (82.8km/hr) than other road segments because the section of the road on which data collected was with no or minor defects.

The significance of difference in mean speed of vehicles using one way ANOVA on different road segments was highly significant (P-value is less than 0.001).

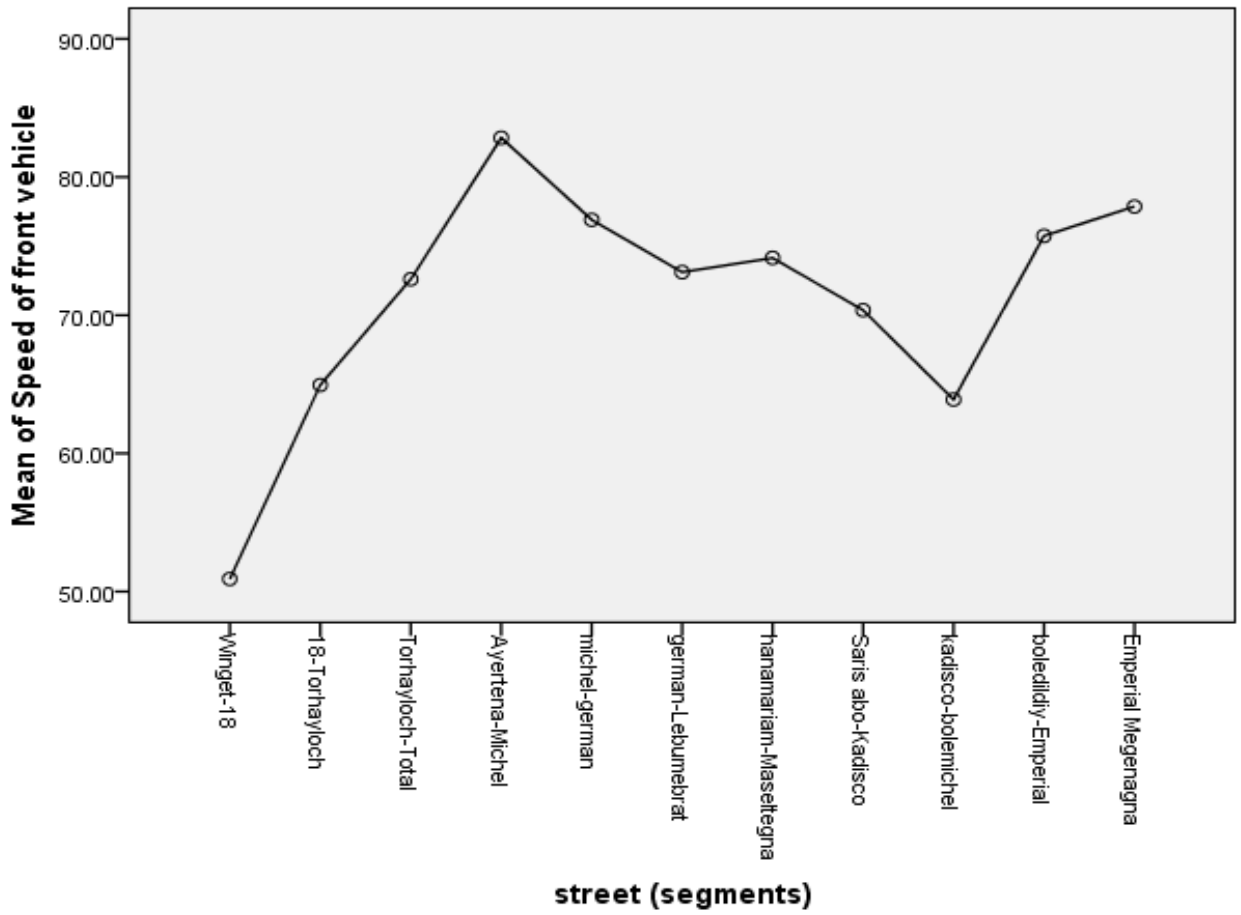
The general test (one way ANOVA) give full evidence to reject HO (The mean speed of front vehicles at each segment is equal) and help to conclude as the mean speed is different at least in one segment(H1) (table 21).

Table 2: Speed of front vehicles difference significance on different segments

Groups	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	72191.529	10	7219.153	8.754	.000
Within Groups	861791.284	1045	824.681		
Total	933982.813	1055			

By using one way ANOVA knowing the segment at which the mean will be different is not possible. From table E-4; Post hoc test (multiple comparisons) was used to know the segment at which the mean is different.

The post hoc test indicated that, the mean speed of the vehicles from Winget to 18 is significantly different from all segment with p value less than 0.05. And also the mean speed from 18 to torhayloch is significantly different from the rest segments except Torhayloch-Total (P=.065),kadisco-bolemichel(P=.799)and Saris abo-Kadisco(P=.192). From table 2 above; the mean speed difference between different segments was significantly different. This means that P-value is < 0.005.



Graph 2: Mean Speed of Front vehicle on different Segments

The visual expression from the graph 2 indicated that, the speed of vehicles from Ayertena to Michel was very high as compared to the other. On the contrary the speed is very low from Winget to 18.

From the analysis output; only 20.8% of the vehicles using winget-18 RA segment are with the speed of LOS A and 76 % of the vehicles using Ayertena-Michael RA segment are with the speed of LOS A, which is significantly different from winget-18 RA road segment. From this and result of chi-Square which gives P-value is less than 0.001; the difference in level of service on different segment is highly significant.

4.3.4. Combined impact of slope of the road, different segment and car following behavior on performance of the ring road

By considering all effects (under scope of this paper) which have an impact on speed of vehicles in car following behavior; those effects are slope, different road segment and whether the front vehicle is heavy or light.

For Winget – 18 RA road segment with positive slope and heavy vehicles front the mean speed is 47.9km/hr and with light vehicles front mean speed is 59.5km/hr. On down grade and heavy vehicles front the mean speed is 38km/hr and with light vehicles front mean speed is 58km/hr.

In another case on Saris Abo-Kadisco road segment with positive slope and heavy vehicles front the mean speed is 66.5km/hr and with light vehicles front mean speed is 66.8km/hr. On down grade and heavy vehicles front the mean speed is 66.5km/hr and with light vehicles front mean speed is 81.6km/hr.

Generally on all segments front vehicles speed were different and concerning grade of the road segments speed of front vehicles on positive grade, negative grade and flat have no smooth pattern. For example on 18-torhayloch road with positive grade segment average speed of front vehicle is 63.65km/hr which is less than negative grade average speed (66.25km/hr). But on Hanamariam-Maseltegna road with positive grade segment average speed of front vehicle is 75.66 km/hr which is less than negative grade average speed (72.63km/hr) in which average speed on positive grade is greater than down grade road lane.

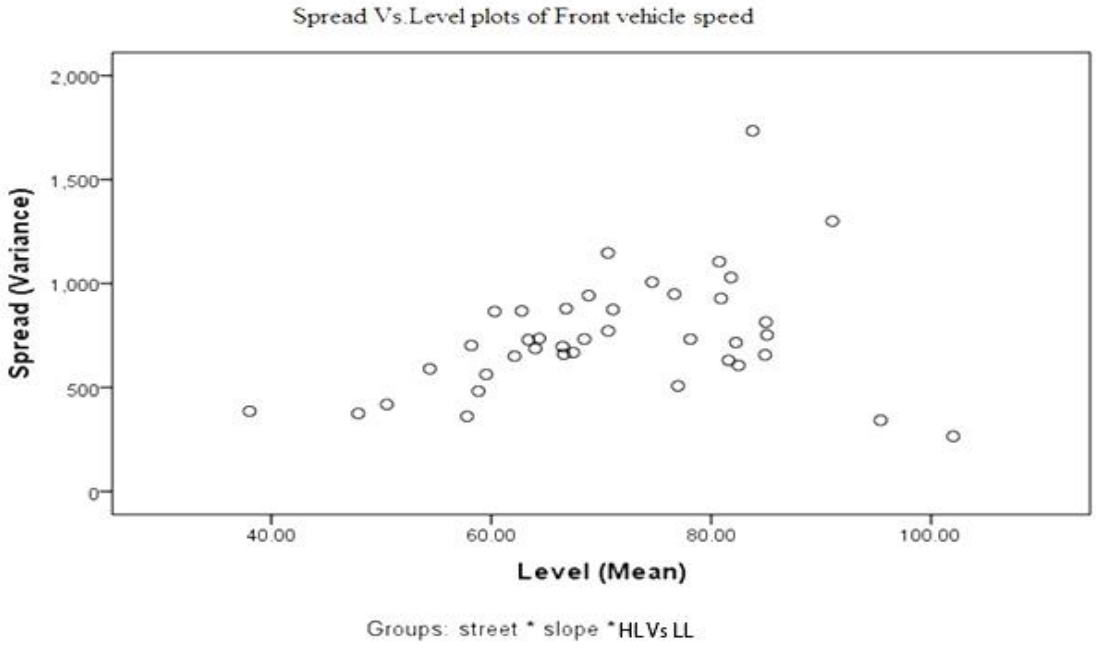
Finally when car following behavior is analyzed it has smooth pattern; which means mean speed during light vehicle following light vehicle is greater than mean speed of vehicles in heavy-light vehicles combination.

Using Univariate analysis of variance combination of all effects on significance of front vehicles speed is as table below.

From the output; slope, combination of (Segment, slope and HS or SS) and combination of (slope and HS or SS) has no significant effect on vehicles speed which have P-value 0.31, 0.458 and 0.061 respectively. Being heavy vehicles front and light vehicles front, types of segment, combination of (segment and slope) and combination of(segment, slope and HS or SS) have significant effect on speed of front vehicles which have P-Value <0.001,0.014 and 0.003 respectively.

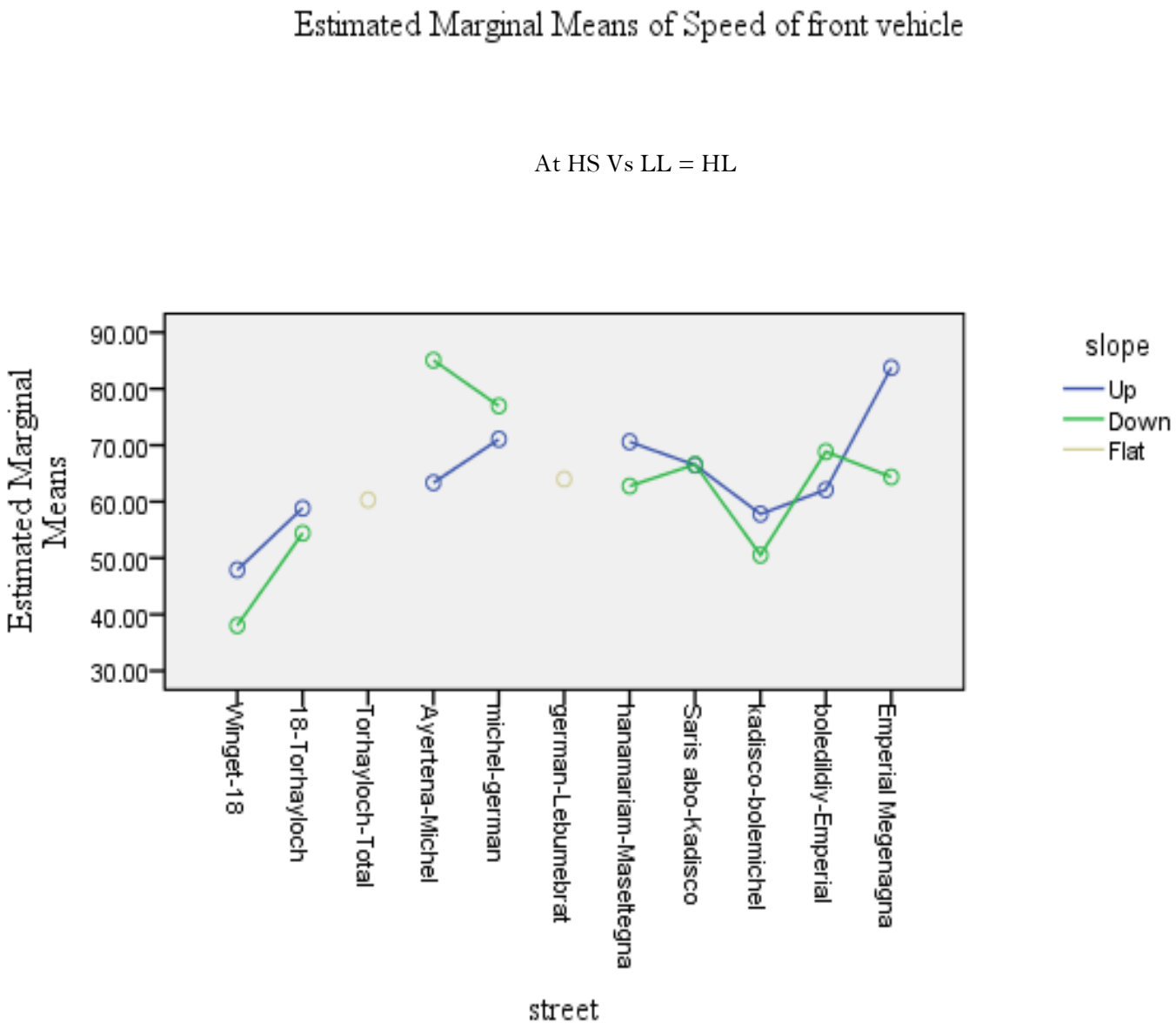
Table 3: Significance level of different segments, Slope, HL Vs LL impact on road performance

Source	df	Mean Square	Sig.
Street(segments)	9	7953.766	.000
Slope	1	767.779	.310
HL vs LL	1	64263.619	.000
Street (segment)* slope	8	1795.016	.014
Street(segment) * HL vs SS	9	725.932	.458
slope * HL vs LL	1	2615.458	.061
Street (segment)* slope * HL vs LL	8	2176.448	.003
Total number of vehicles	1056		



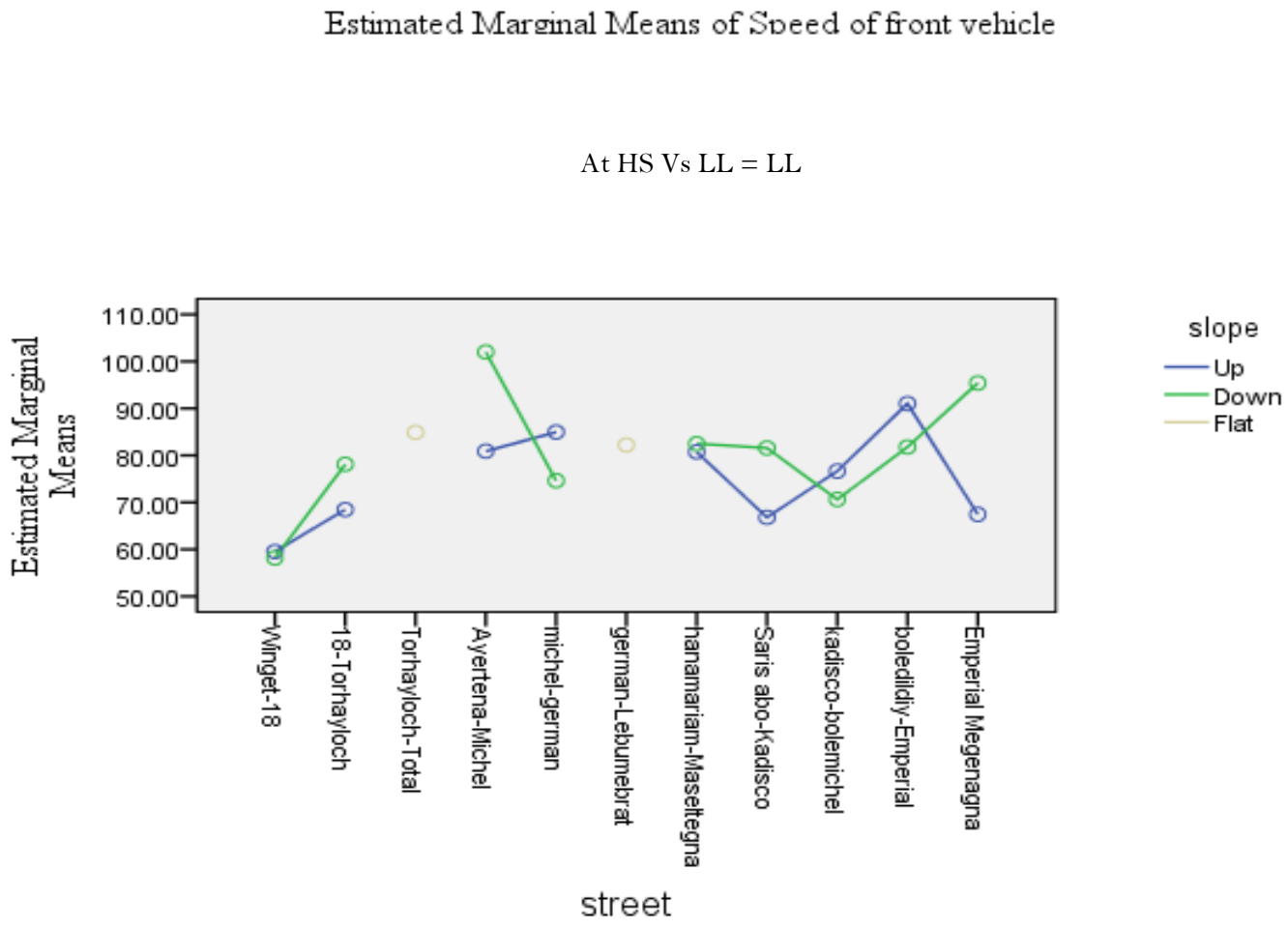
Graph 3: Mean Speed of front vehicle

Since there is somewhat an apparent pattern in this plot, so there is indication of such a relationship here or a ring road with different segment (street), different slope and different vehicle combination (HS or SS) have a different mean speed.



Graph 4 : Estimated Marginal Means for HL Combination

When Light vehicle following heavy vehicle option is considered and speed of front vehicle is analyzed; there is interaction effect between lines; that means lines cross each other (not parallel) and when one of the lines goes downward the other goes upward. Therefore there is a significant effect on mean speed on different segment.



Graph 5 **:** Estimated marginal means for LL combination

When Light vehicle following Light vehicle option is considered and speed of front vehicle is analyzed; there is interaction effect between lines; that means lines cross each other (not parallel) and when one of the lines goes downward the other goes upward. Therefore there is a significant effect on mean speed on different segment.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

Presence of heavy vehicles on the same lane with light vehicles has severe impact on performance of the road. That means Mean Speed of heavy vehicles is much less than means speed of light vehicle. Concerning safety many light vehicles faced crash because of illegal lane change. Which shows that when frequency of lane change increase there is very slowly moving vehicle or there is discomfort of following the slowly moving vehicles. Almost all vehicles follow or change lane freely when following slowly moving vehicles and High number of light vehicles following slowly moving heavy vehicles change lane uncomfortably and follow if there is no another option. This all shows common lane utilization has an effect on safety of vehicles, reliability (consistency) of speed, mobility (average travel time), level of service of the road. Finally it is significant that road segment with light following light vehicles have better performance than the road on which light vehicles following heavy vehicles.

Removing of heavy vehicles from lane of the light vehicles on the midblock ring road will improve the level of service, reliability and average travel time of the other vehicles.

RECOMMENDATIONS

Based on the study findings the result enabled the researcher to drive the following recommendations for concerned body:

- Develop policy which is lane restriction for heavy and light vehicles on midblock ring roads
- Develop seriously applicable policy for vehicles with speed less than 50km/hr to use frontage ring road lane.
- Construct off street parking for taxis rather than using for parking frontage lane
- Maintain and post additional traffic signs on ring roads rather than constructing speed braker.

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APPENDIX A: Information of the Research

Title of the research: **Impacts of Common Lane Use of Heavy and Light vehicles on Performance of Addis Ababa Midblock (Ring) Road Sections.**

Name of principal investigator: **Anbessa Bekele**

Name of Advisor**: Dr. Ashenafi Aregawi**

Name of the organization: **Addis Ababa Science and Technology University**

Name of sponsor: **Ethiopian Roads Authority**

Research area: Winget-18 RA (2.7km), 18 RA-Torhayloch(2.66km), Torhayloch-Total RA(2.17km), Ayer tena RA-Mikeal RA(3.2km), Mikeal RA-German RA(1.36km), German RA-Lebumebrathayle RA(1.79km), Hanamariam-Maseltegna(2.47km), Saris Abo RA –kadisco RA(2.12km), Kadisco RA-Bole Mikeal RA(2.5km), Bole dildiy(airport)-Emperial RA(1.9km),Emperial RA-Megenagna(2.1km).

APPENDIX B –Participants response frequency

Table B- 1: Detail of participants' response frequency

PARAMETERS	Frequency	Percent (%)
Vehicle Category		
With more than four tyre(Heavy)	101	50
With four tyre(Light)	101	50
Speed during free of Congestion		
Greater than 80km/hr	34	16.8
70-80 km/hr	50	24.8
60-70km/hr	56	27.7
50-60km/hr	56	27.7
Less than 50km/hr	6	3.0
Decision if follow slow light vehicle		
Change lane freely	7	3.5
Change lane uncomfortably	1	.5
Follow by decreasing speed	1	.5
Change lane freely, follow by decreasing speed	163	80.7
Change lane uncomfortably, follow by decreasing speed	30	14.9
Decision if follow slow Heavy vehicle		
Change lane freely	1	.5
Change lane uncomfortably	8	4.0
Follow by decreasing speed	1	.5
Change lane freely, follow by decreasing speed	29	14.4
Change lane uncomfortably, follow by decreasing speed	163	80.7
Is that Horizontal curve has impact on your speed?		
Yes	199	98.5
No	3	1.5
If yes to what extent?		
Highly affect	15	7.4
Moderately affect	179	88.6
Less impact	5	2.5
Is that Grade of vertical curve has impact on your speed?		
Yes	199	
No	3	
If yes to what extent?		
Highly affect	39	19.3
Moderately affect	156	77.2

Less impact	4	2
What is the impact of following slowly moving heavy vehicle?		
Sight distance problem		
Discomfort	1	.5
Enforce to change lane	17	8.4
Others(splash of mud or wet dirty during rainy season)		
Sight distance problem, Discomfort and Enforce to change lane	122	60.4
Discomfort and Enforce to change lane	54	26.7
Sight distance problem, Discomfort, enforce to change lane and others	8	4
What is the impact of following slowly moving Light vehicle?		
Sight distance problem	1	.5
Discomfort		
Enforce to change lane	185	91.6
Other(splash of mud during rainy season)		
Sight distance problem, Discomfort and Enforce to change lane		
Discomfort and Enforce to change lane	16	7.9
Sight distance problem, Discomfort, enforce to change lane and others		
If you are unable to overtake slowly moving heavy vehicle which position is comfortable?		
Following by decreasing speed	4	2
Side to side using adjacent lane	175	86.6
Both position	23	11.4
If you are unable to overtake slowly moving light vehicle which position is comfortable?		
Following by decreasing speed	5	2.5
Side to side using adjacent lane	32	15.8
Both position	165	81.7

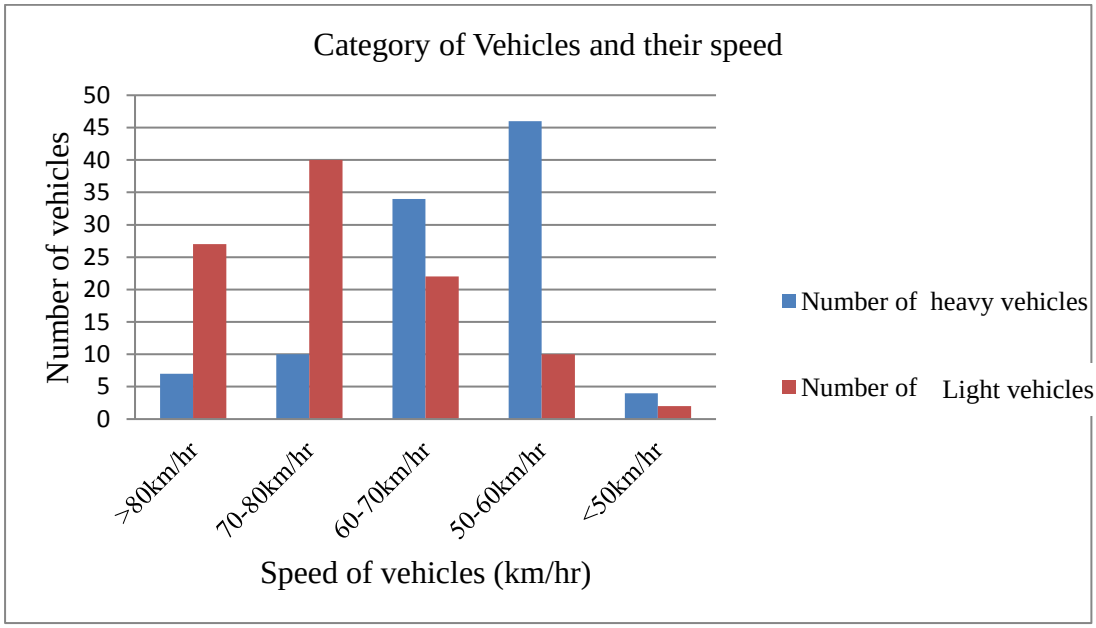


Figure B- 1: Category of Vehicles and their free speed

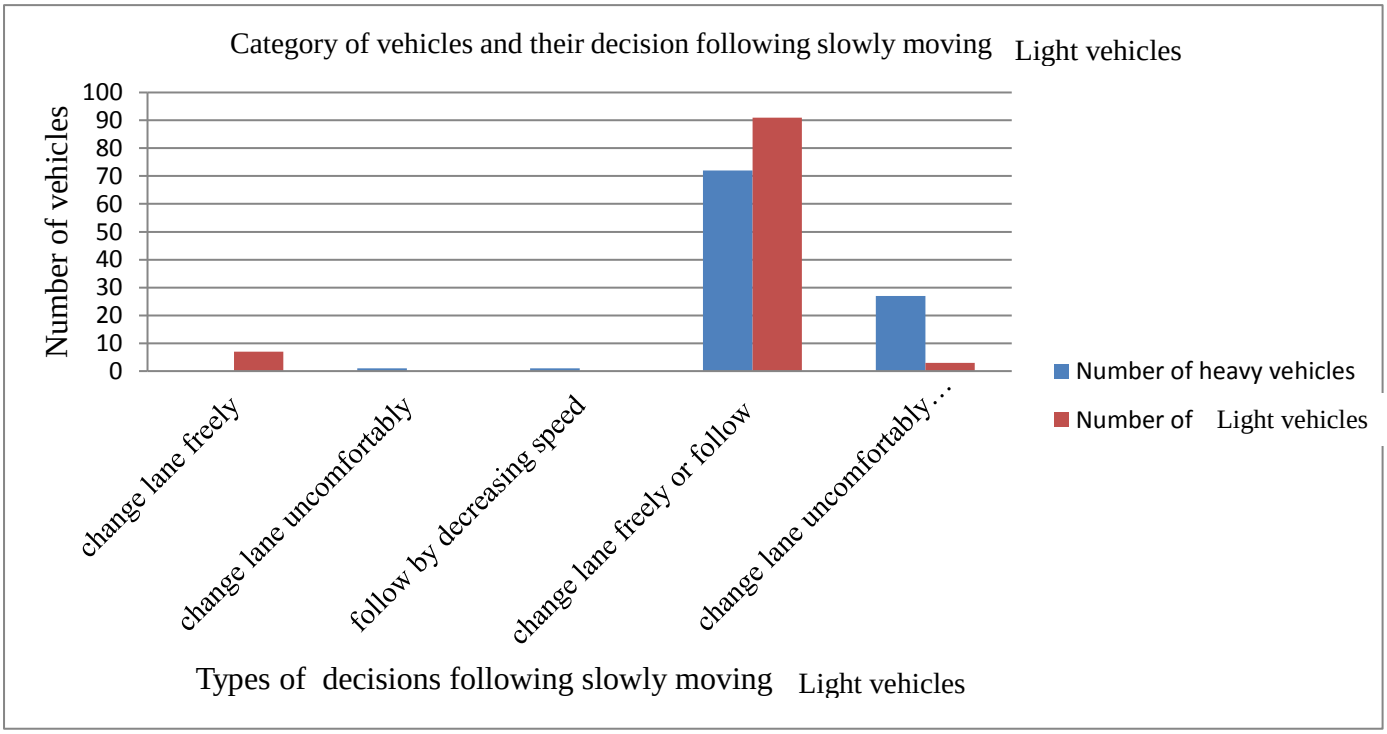


Figure B- 2: Category of Vehicle Vs Decisions Following Light vehicle

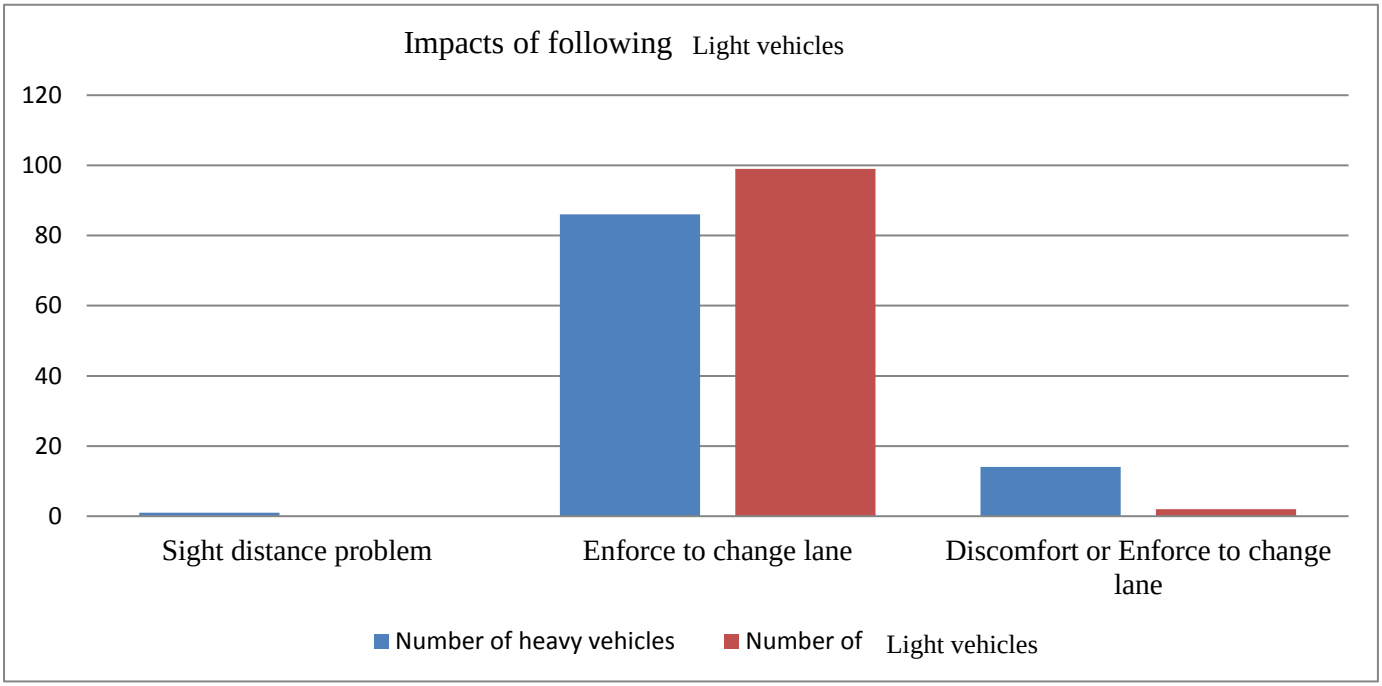


Figure B- 3: Problems encountered following slowly moving light vehicle

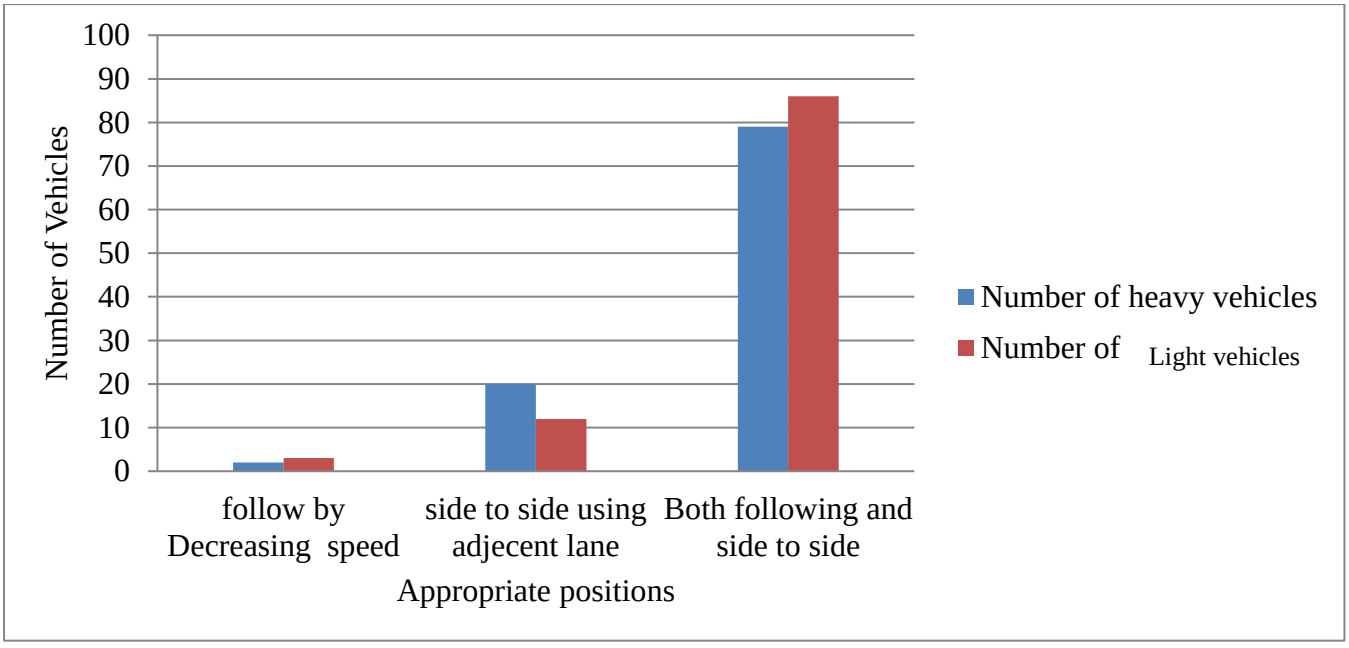


Figure B- 4: Appropriate Positions Following Light vehicle

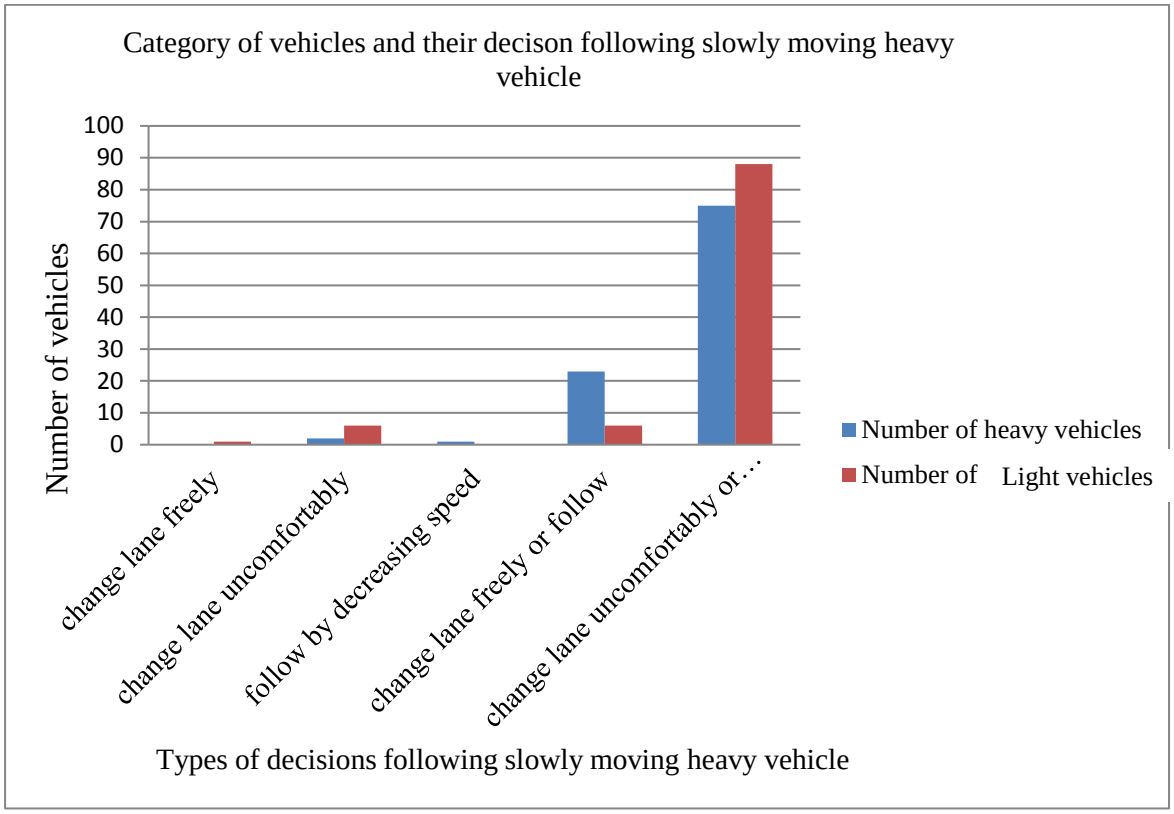


Figure B- 5: Category of vehicle vs. Decisions of vehicles following slowly moving heavy vehicle

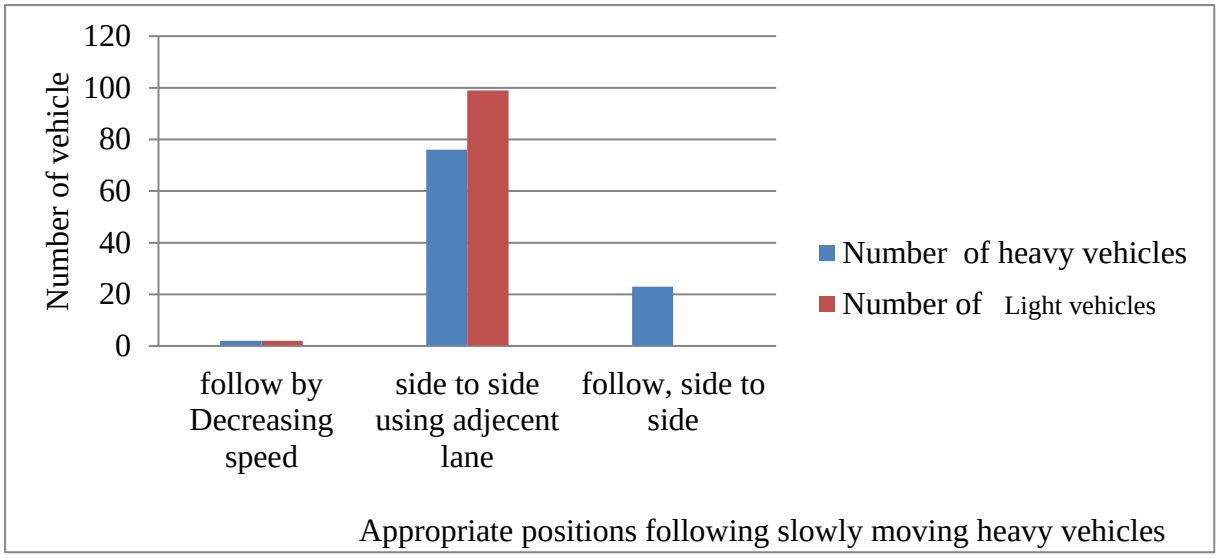


Figure B- 6: Appropriate Positions Following Heavy Vehicle

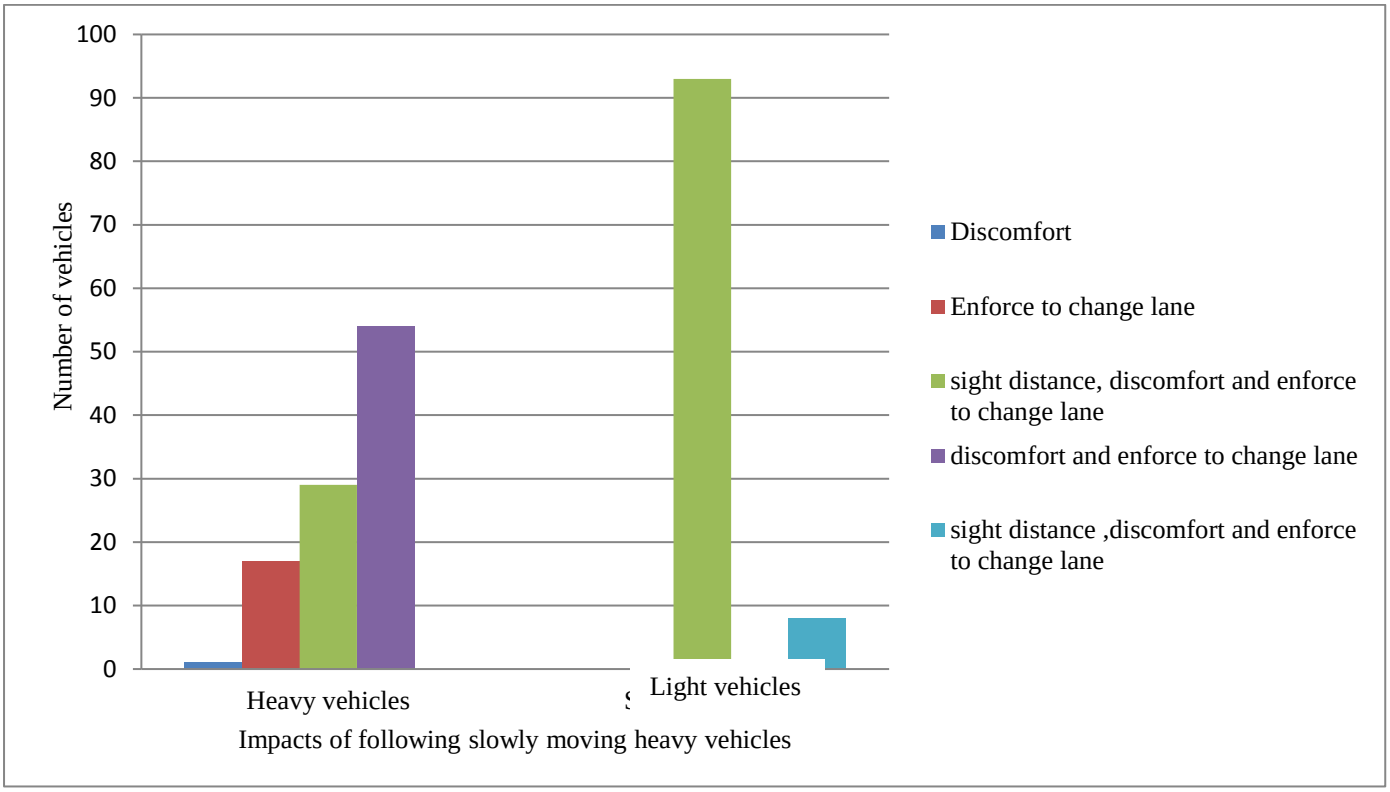


Figure B- 7: Category of Vehicle Vs Problems encountered following heavy vehicles

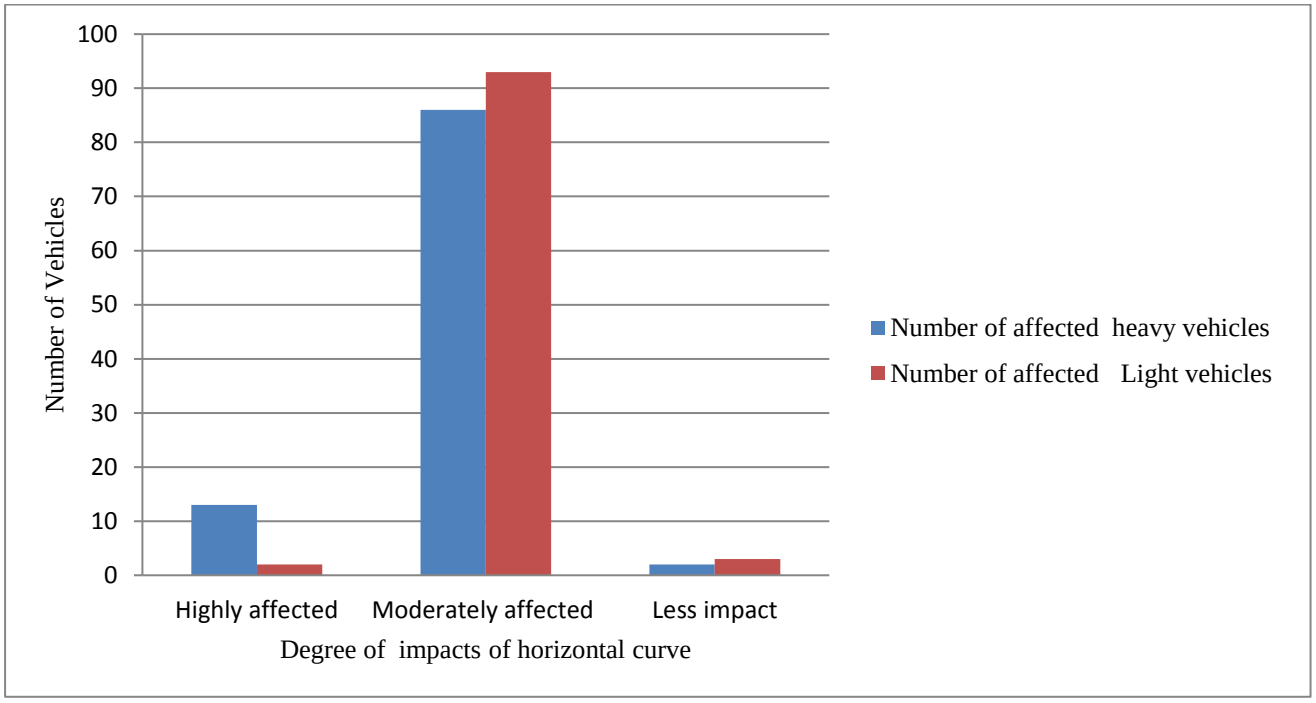


Figure B- 8: Impacts of horizontal curve on performance of the ring road

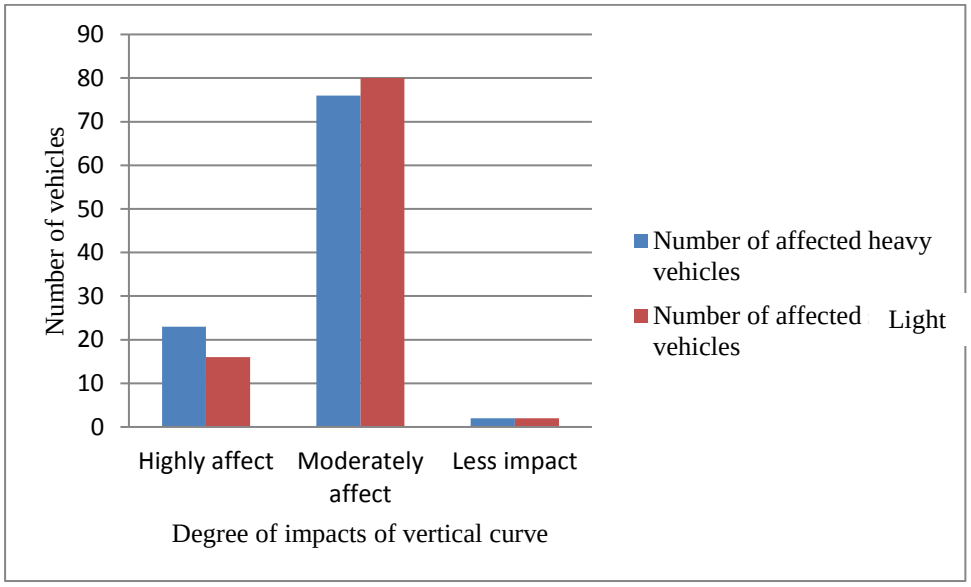


Figure B- 9: Impacts of vertical curve on the performance of the ring road

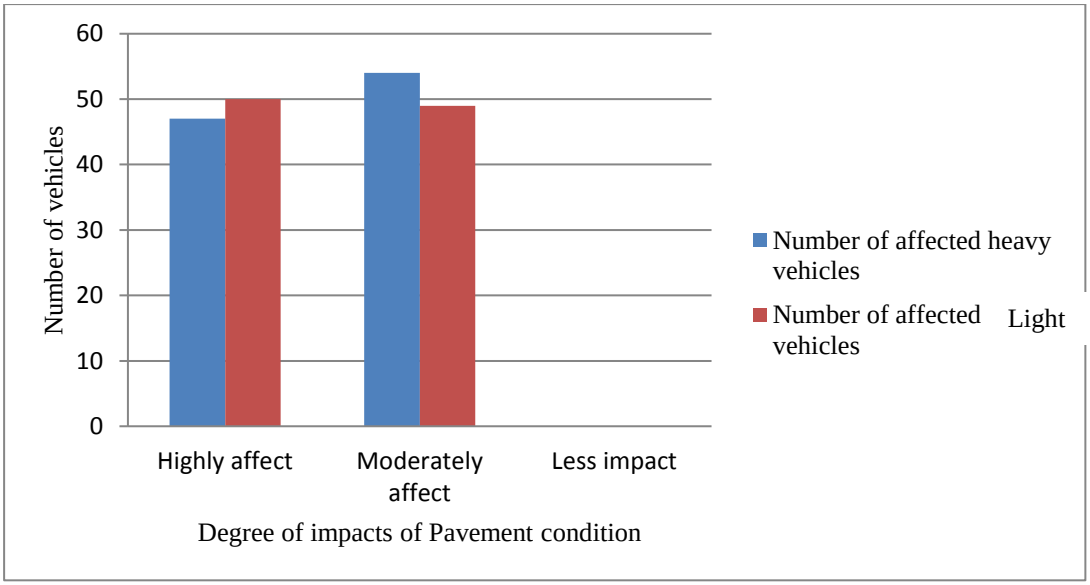


Figure B- 10: Impacts of pavement condition of the performance of the ring road

APPENDIX C- Causes and frequency of vehicles Crash

Table C- 1: Crash frequency in different Sub City

Sub city	Crash Frequency	Percent
Nifas silk lafto	30	28.8
Kolf keranio	46	44.2
Bole	28	26.9
Total	104	100.0

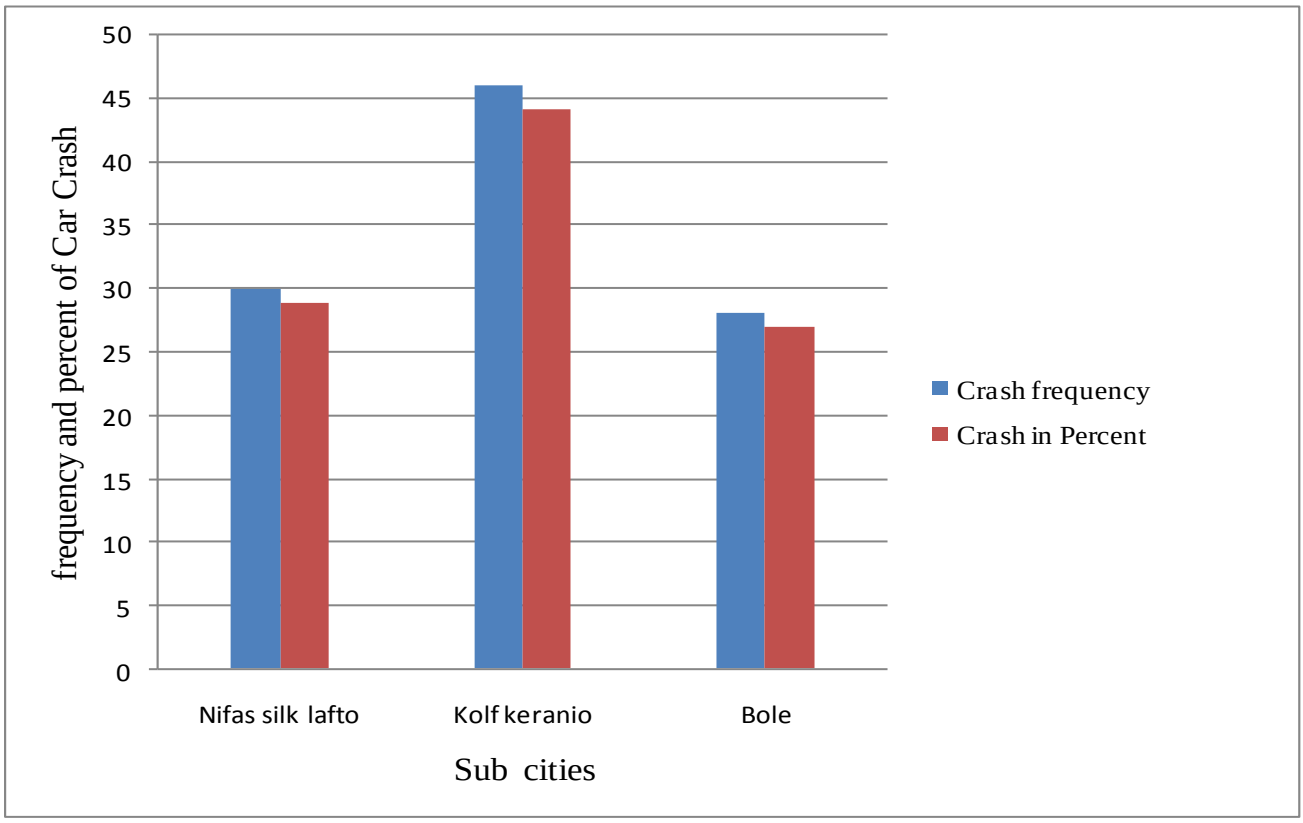


Figure C- 1: Crash frequency in different Sub City

Table C- 2: Causes of vehicle crash

Reason of crash	**Frequency**	**Percent**
HL illegally using opposite lane	1	1.0
HL No enough head way	18	17.3
HL illegal lane change	14	13.5
HL Illegal over take	6	5.8
HL unacceptable Driving back	6	5.8
HL Vehicle out of control	3	2.9
LL No enough head way	9	8.7
LL illegal lane change	25	24.0
LL Illegal over take	10	9.6
LL unacceptable Driving back	2	1.9
HH No enough head way	2	1.9
HH illegal lane change	3	2.9
HH Illegal over take	3	2.9
HH unacceptable Driving back	2	1.9

APPENDIX D: Participant's analysis result

Table D- 1: Mean speed difference on different grade of the road

Max.grade on study area in %	No. of vehicles	Mean speed (km/hr)	Std. Deviation (km/hr)	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Up (5.5%)	432	69.9	30.27505	1.45661	66.9999	72.7257
Down (5.5%)	432	71.8	29.59307	1.42380	69.0315	74.6284
Flat	192	72.9	28.94455	2.08889	68.7382	76.9787
Total	1056	71.2	29.75385	.91561	69.4156	73.0088

Table D- 2: LOS using Front Vehicles on different slopes

Slope	LOS using Front Vehicles and No of vehicles in %					
	A	B	C	D	E	F
Up	55.09	14.12	2.78	6.02	18.52	3.47
Down	59.72	9.95	3.70	6.02	15.51	5.09
Flat	64.06	8.33	1.56	3.13	20.31	2.60
Total	58.62	11.36	2.94	5.49	17.61	3.98

Table D- 3: Analysis of speed of rear vehicle (light vehicle) for both HL and LL combination

Hypothesis	t-test for Equality of Means					
	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Equal variances assumed	1054	.000	-13.17103	1.82273	-6.74762	-9.59444
Equal variances not assumed	1048.776	.000	-13.17103	1.82273	-6.74764	-9.59442

Table D- 4: LOS of the midblock ring road using rear vehicle and No of vehicles in percent

Category of vehicle	LOS using rear vehicle and No of vehicles in %					
	A	B	C	D	E	F
Light with heavy	53.6	11.6	2.7	6.6	21.8	3.8
Light with Light	73.5	4.5	1.9	7.6	11.6	0.9

APPENDIX E: Video data analysis result

Table E- 1: Speed of Front Vehicles on different Segments

Segments	Number of vehicles	Mean speed in km/hr	Std. Deviation	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Winget-18 RA	96	50.9125	23.81035	46.0881	55.7369
18 RA-Torhayloch	96	64.9515	26.43253	59.5958	70.3072
Torhayloch-Total RA	96	72.6015	30.09970	66.5028	78.7003
Ayertena RA-Michael RA	96	82.8332	28.95930	76.9655	88.7009
Michael RA-German RA	96	76.9069	28.32042	71.1686	82.6451
German RA-Lebumebrat RA	96	73.1153	27.89744	67.4628	78.7679
Hanamariam-Maseltegna	96	74.1467	31.08894	67.8475	80.4459
Saris abo RA-Kadisco RA	96	70.3611	27.13915	64.8622	75.8600
Kadisco RA-Bolemichel RA	96	63.8954	26.69509	58.4865	69.3043
Boledildiy-Emperial RA	96	75.7413	32.77606	69.1003	82.3824
Emperial RA- Megenagna	96	77.8687	31.47977	71.4903	84.2471
Total	1056	71.2122	29.75385	69.4156	73.0088

Table E- 2: Multiple Comparisons of speed on different Grades

(I) slope (%)	(J)Slope (%)	Mean Difference (I-J) (km/hr)	Std. Error	Sig.
Up	Down	-1.96714	2.02482	.332
	Flat	-2.99562	2.58115	.246
Down	Up	1.96714	2.02482	.332
	Flat	-1.02848	2.58115	.690
Flat	Up	2.99562	2.58115	.246
	Down	1.02848	2.58115	.690

Table E- 3: Significance Level of Slope on LOS using front vehicles

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.325[a]	10	.091

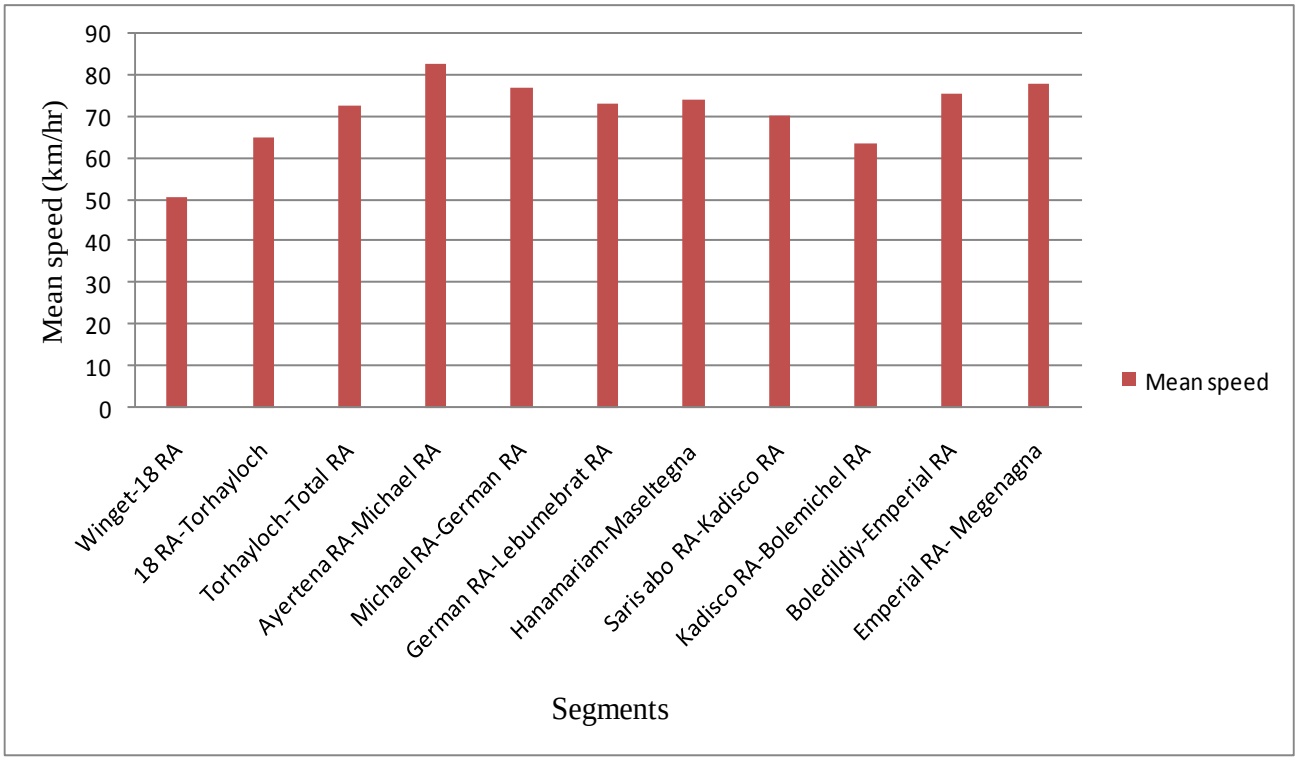


Figure E- 1: Speed of Front Vehicles on different segments

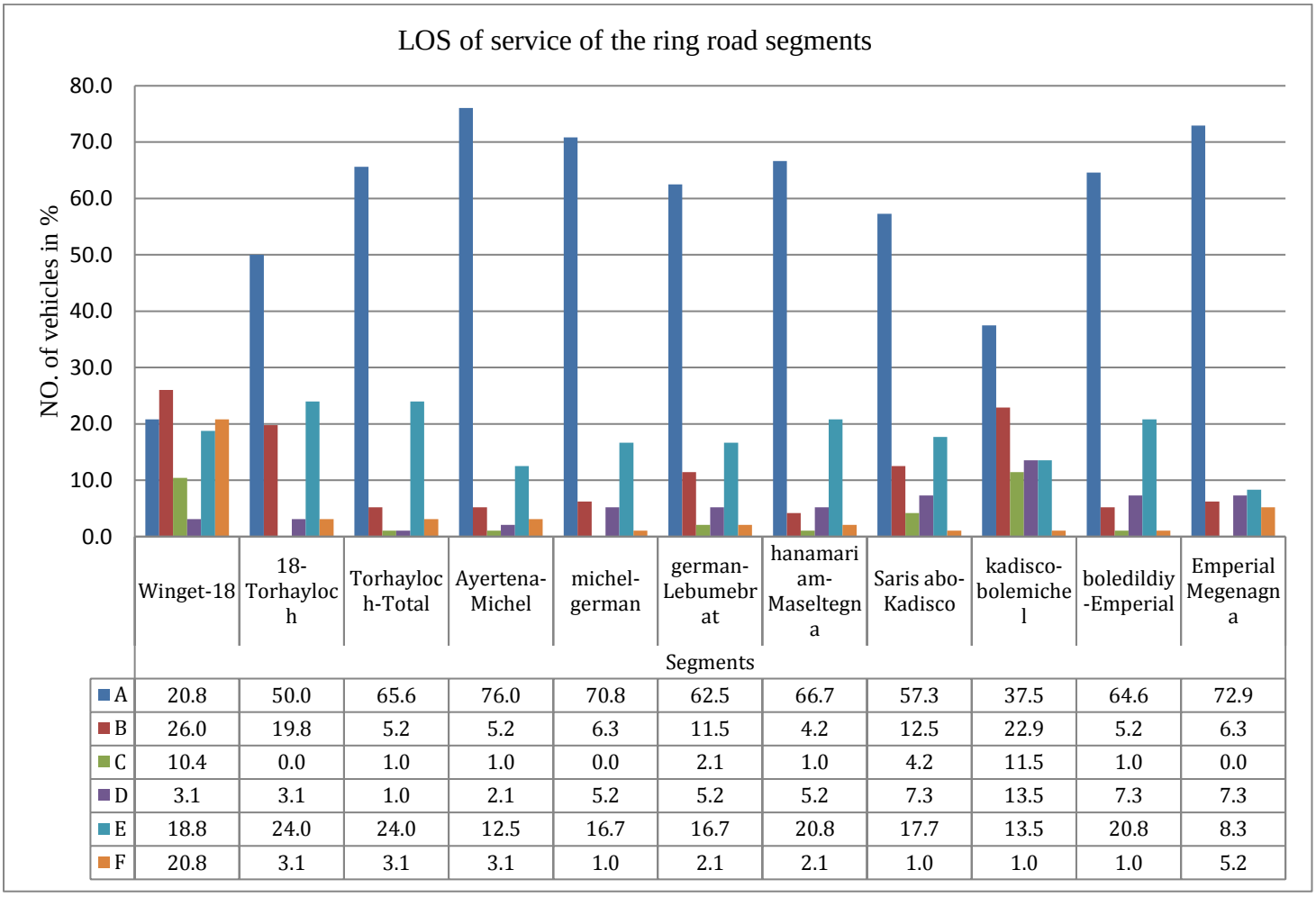
Table E- 4: Comparison between Mean Speeds on Each Segment with Other Segments

(I) street or segment name	(J) street or segments name	Mean Difference (I-J) in (km/hr)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Winget-18	18-Torhayloch	-14.03898*	4.14498	.001	-22.1724	-5.9056
	Torhayloch-Total	-21.68901*	4.14498	.000	-29.8224	-13.5556
	Ayertena-Michel	-31.92065*	4.14498	.000	-40.0541	-23.7872
	Michel-German	-25.99437*	4.14498	.000	-34.1278	-17.8609
	German-Lebumebrat	-22.20280*	4.14498	.000	-30.3362	-14.0694
	Hanamariam-Maseltegna	-23.23419*	4.14498	.000	-31.3676	-15.1008
	Saris Abo-Kadisco	-19.44859*	4.14498	.000	-27.5820	-11.3152
	Kadisco-Bolemichel	-12.98288*	4.14498	.002	-21.1163	-4.8495
	Boledildiy-Emperial	-24.82883*	4.14498	.000	-32.9623	-16.6954
	Emperial-Megenagna	-26.95617*	4.14498	.000	-35.0896	-18.8227
18-Torhayloch	Winget-18	14.03898*	4.14498	.001	5.9056	22.1724

	Torhayloch-Total	-7.65002	4.14498	.065	-15.7835	.4834
	Ayertena-Michel	-17.88167*	4.14498	.000	-26.0151	-9.7482
	Michel-German	-11.95538*	4.14498	.004	-20.0888	-3.8220
	German-Lebumebrat	-8.16382*	4.14498	.049	-16.2972	-.0304
	Hanamariam-Maseltegna	-9.19521*	4.14498	.027	-17.3286	-1.0618
	Saris Abo-Kadisco	-5.40961	4.14498	.192	-13.5430	2.7238
	Kadisco-Bolemichel	1.05610	4.14498	.799	-7.0773	9.1895
	Boledildiy-Emperial	-10.78984*	4.14498	.009	-18.9233	-2.6564
	Emperialmegenagna	-12.91718*	4.14498	.002	-21.0506	-4.7838
Torhayloch-Total	Winget-18	21.68901*	4.14498	.000	13.5556	29.8224
	18-Torhayloch	7.65002	4.14498	.065	-.4834	15.7835
	Ayertena-Michel	-10.23165*	4.14498	.014	-18.3651	-2.0982
	Michel-German	-4.30536	4.14498	.299	-12.4388	3.8281
	German-Lebumebrat	-.51380	4.14498	.901	-8.6472	7.6196
	Hanamariam-Maseltegna	-1.54519	4.14498	.709	-9.6786	6.5882
	Saris Abo-Kadisco	2.24041	4.14498	.589	-5.8930	10.3738
	Kadisco-Bolemichel	8.70612*	4.14498	.036	.5727	16.8396
	Boledildiy-Emperial	-3.13982	4.14498	.449	-11.2732	4.9936
	Emperial-Megenagna	-5.26716	4.14498	.204	-13.4006	2.8663
Ayertena-Michel	Winget-18	31.92065*	4.14498	.000	23.7872	40.0541
	18-Torhayloch	17.88167*	4.14498	.000	9.7482	26.0151
	Torhayloch-Total	10.23165*	4.14498	.014	2.0982	18.3651
	Michel-German	5.92628	4.14498	.153	-2.2071	14.0597
	German-Lebumebrat	9.71785*	4.14498	.019	1.5844	17.8513
	Hanamariam-Maseltegna	8.68646*	4.14498	.036	.5530	16.8199
	Saris Abo-Kadisco	12.47206*	4.14498	.003	4.3386	20.6055
	Kadisco-Bolemichel	18.93777*	4.14498	.000	10.8043	27.0712
	Boledildiy-Emperial	7.09183	4.14498	.087	-1.0416	15.2253
	Emperial-Megenagna	4.96448	4.14498	.231	-3.1689	13.0979
Michael-German	Winget-18	25.99437*	4.14498	.000	17.8609	34.1278
	18-Torhayloch	11.95538*	4.14498	.004	3.8220	20.0888
	Torhayloch-Total	4.30536	4.14498	.299	-3.8281	12.4388
	Ayertena-Michel	-5.92628	4.14498	.153	-14.0597	2.2071
	German-Lebumebrat	3.79156	4.14498	.361	-4.3419	11.9250
	Hanamariam-Maseltegna	2.76017	4.14498	.506	-5.3733	10.8936
	Saris Abo-Kadisco	6.54577	4.14498	.115	-1.5877	14.6792
	Kadisco-Bolemichel	13.01148*	4.14498	.002	4.8781	21.1449
	Boledildiy-Emperial	1.16554	4.14498	.779	-6.9679	9.2990
	Emperial-Megenagna	-.96180	4.14498	.817	-9.0952	7.1716

German-Lebumebrat	Winget-18	22.20280*	4.14498	.000	14.0694	30.3362
	18-Torhayloch	8.16382*	4.14498	.049	.0304	16.2972
	Torhayloch-Total	.51380	4.14498	.901	-7.6196	8.6472
	Ayertena-Michel	-9.71785*	4.14498	.019	-17.8513	-1.5844
	Michel-German	-3.79156	4.14498	.361	-11.9250	4.3419
	Hanamariam-Maseltegna	-1.03139	4.14498	.804	-9.1648	7.1020
	Saris Abo-Kadisco	2.75421	4.14498	.507	-5.3792	10.8876
	Kadisco-Bolemichel	9.21992*	4.14498	.026	1.0865	17.3533
	Boledildiy-Emperial	-2.62602	4.14498	.527	-10.7595	5.5074
	Emperial-Megenagna	-4.75336	4.14498	.252	-12.8868	3.3801
Hana mariam-Maseltegna	Winget-18	23.23419*	4.14498	.000	15.1008	31.3676
	18-Torhayloch	9.19521*	4.14498	.027	1.0618	17.3286
	Torhayloch-Total	1.54519	4.14498	.709	-6.5882	9.6786
	Ayertena-Michel	-8.68646*	4.14498	.036	-16.8199	-.5530
	Michel-German	-2.76017	4.14498	.506	-10.8936	5.3733
	German-Lebumebrat	1.03139	4.14498	.804	-7.1020	9.1648
	Saris Abo-Kadisco	3.78560	4.14498	.361	-4.3478	11.9190
	Kadisco-Bolemichel	10.25131*	4.14498	.014	2.1179	18.3847
	Boledildiy-Emperial	-1.59463	4.14498	.701	-9.7281	6.5388
	Emperial-Megenagna	-3.72197	4.14498	.369	-11.8554	4.4115
Saris Abo-Kadisco	Winget-18	19.44859*	4.14498	.000	11.3152	27.5820
	18-Torhayloch	5.40961	4.14498	.192	-2.7238	13.5430
	Torhayloch-Total	-2.24041	4.14498	.589	-10.3738	5.8930
	Ayertena-Michel	-12.47206*	4.14498	.003	-20.6055	-4.3386
	Michel-German	-6.54577	4.14498	.115	-14.6792	1.5877
	German-Lebumebrat	-2.75421	4.14498	.507	-10.8876	5.3792
	Hanamariam-Maseltegna	-3.78560	4.14498	.361	-11.9190	4.3478
	Kadisco-Bolemichel	6.46571	4.14498	.119	-1.6677	14.5991
	Boledildiy-Emperial	-5.38023	4.14498	.195	-13.5137	2.7532
	Emperial-Megenagna	-7.50757	4.14498	.070	-15.6410	.6259
Kadisco-Bolemichel	Winget-18	12.98288*	4.14498	.002	4.8495	21.1163
	18-Torhayloch	-1.05610	4.14498	.799	-9.1895	7.0773
	Torhayloch-Total	-8.70612*	4.14498	.036	-16.8396	-.5727
	Ayertena-Michel	-18.93777*	4.14498	.000	-27.0712	-10.8043
	Michel-German	-13.01148*	4.14498	.002	-21.1449	-4.8781
	German-Lebumebrat	-9.21992*	4.14498	.026	-17.3533	-1.0865
	Hanamariam-Maseltegna	-10.25131*	4.14498	.014	-18.3847	-2.1179
	Saris Abo-Kadisco	-6.46571	4.14498	.119	-14.5991	1.6677
	Boledildiy-Emperial	-11.84594*	4.14498	.004	-19.9794	-3.7125
	Emperial-Megenagna	-13.97328*	4.14498	.001	-22.1067	-5.8399
Boledildiy-	Winget-18	24.82883*	4.14498	.000	16.6954	32.9623
	18-Torhayloch	10.78984*	4.14498	.009	2.6564	18.9233

Emperial	Torhayloch-Total	3.13982	4.14498	.449	-4.9936	11.2732
	Ayertena-Michel	-7.09183	4.14498	.087	-15.2253	1.0416
	Michel-German	-1.16554	4.14498	.779	-9.2990	6.9679
	German-Lebumebrat	2.62602	4.14498	.527	-5.5074	10.7595
	Hanamariam-Maseltegna	1.59463	4.14498	.701	-6.5388	9.7281
	Saris Abo-Kadisco	5.38023	4.14498	.195	-2.7532	13.5137
	Kadisco-Bolemichel	11.84594*	4.14498	.004	3.7125	19.9794
	Emperial-Megenagna	-2.12734	4.14498	.608	-10.2608	6.0061
Emperial-Megenagna	Winget-18	26.95617*	4.14498	.000	18.8227	35.0896
	18-Torhayloch	12.91718*	4.14498	.002	4.7838	21.0506
	Torhayloch-Total	5.26716	4.14498	.204	-2.8663	13.4006
	Ayertena-Michel	-4.96448	4.14498	.231	-13.0979	3.1689
	Michel-German	.96180	4.14498	.817	-7.1716	9.0952
	German-Lebumebrat	4.75336	4.14498	.252	-3.3801	12.8868
	Hanamariam-Maseltegna	3.72197	4.14498	.369	-4.4115	11.8554
	Saris Abo-Kadisco	7.50757	4.14498	.070	-.6259	15.6410
	Kadisco-Bolemichel	13.97328*	4.14498	.001	5.8399	22.1067
	Boledildiy-Emperial	2.12734	4.14498	.608	-6.0061	10.2608



	Winget-18	18-Torhayloch	Torhayloch-Total	Ayertena-Michel	michel-german	german-Lebumebrat	hanamariam-Maseltegna	Saris abo-Kadisco	kadisco-bolemichel	boledildiy-Emperial	Emperial Megenagna
A	20.8	50.0	65.6	76.0	70.8	62.5	66.7	57.3	37.5	64.6	72.9
B	26.0	19.8	5.2	5.2	6.3	11.5	4.2	12.5	22.9	5.2	6.3
C	10.4	0.0	1.0	1.0	0.0	2.1	1.0	4.2	11.5	1.0	0.0
D	3.1	3.1	1.0	2.1	5.2	5.2	5.2	7.3	13.5	7.3	7.3
E	18.8	24.0	24.0	12.5	16.7	16.7	20.8	17.7	13.5	20.8	8.3
F	20.8	3.1	3.1	3.1	1.0	2.1	2.1	1.0	1.0	1.0	5.2

Figure E- 2: Segments Vs LOS of Road Using Speed of Front Vehicles

Table E- 5: Significance level of LOS difference of road using speed of front vehicle for different Segment

Chi-Square Test	Value	Df	Assumption. Sig. (2-sided)
Pearson Chi-Square	268.059[a]	50	.000

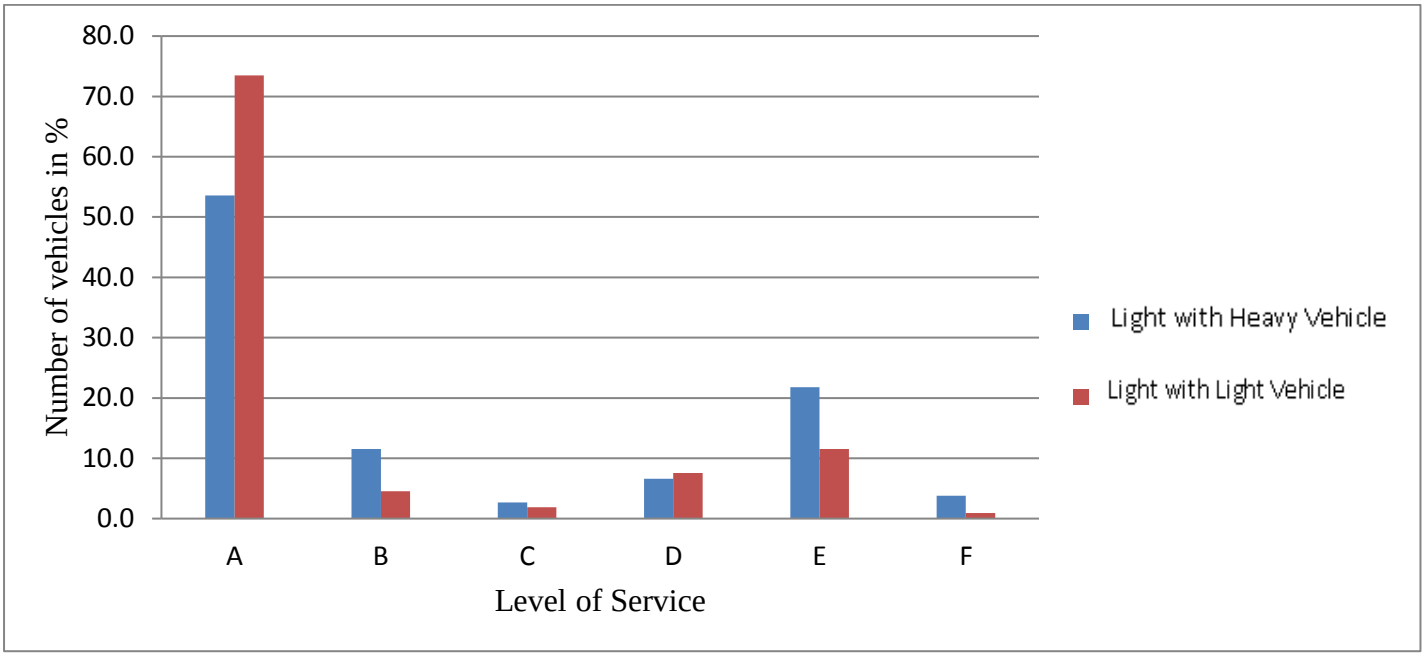


Figure E- 3: LOS of the ring road using rear vehicles

Table E- 6: Significance Level of LOS using rear vehicle in different combination

Chi-Square Tests	Value	Df	Assumption. Sig. (2-sided)
Pearson Chi-Square	59.105[a]	5	.000

Table E- 7: Mean Speed of Front Vehicle Considering different Segment, Slope, HL and LL combination

Street (Segments)	Slope	Heavy with Light vehicle vs. Light with Light vehicle	Mean speed in km/hr	Ltd. Deviation	Number of vehicles
Winget-18	Up	HL	47.9029	19.36979	24
		LL	59.5408	23.72125	24
		Total	53.7219	22.21590	48
	Down	HL	38.0216	19.64714	24
		LL	58.1848	26.49644	24
		Total	48.1032	25.22422	48
	Total	HL	42.9623	19.93568	48
		LL	58.8628	24.88763	48
		Total	50.9125	23.81035	96
18-Torhayloch	Up	HL	58.8333	21.96224	24
		LL	68.4666	27.07543	24
		Total	63.6500	24.86913	48
	Down	HL	54.4089	24.28280	24
		LL	78.0972	27.06505	24
		Total	66.2530	28.11209	48
	Total	HL	56.6211	23.01284	48
		LL	73.2819	27.21924	48
		Total	64.9515	26.43253	96
Torhayloch-Total	Flat	HL	60.3077	29.42285	48
		LL	84.8953	25.62911	48
		Total	72.6015	30.09970	96
	Total	HL	60.3077	29.42285	48
		LL	84.8953	25.62911	48
		Total	72.6015	30.09970	96
Ayertena-Michel	Up	HL	63.3646	27.00778	24
		LL	80.8920	30.46854	24
		Total	72.1283	29.82745	48
	Down	HL	85.0713	27.43349	24
		LL	102.0048	16.29147	24

		Total	93.5380	23.90366	48
	Total	HL	74.2180	29.07823	48
		LL	91.4484	26.41933	48
		Total	82.8332	28.95930	96
Michael-German	Up	HL	71.0645	29.58238	24
		LL	84.9653	28.54197	24
		Total	78.0149	29.60135	48
	Down	HL	76.9767	22.52839	24
		LL	74.6210	31.72810	24
		Total	75.7989	27.24718	48
	Total	HL	74.0206	26.18279	48
		LL	79.7931	30.30846	48
		Total	76.9069	28.32042	96
German-Lebumebrat	Flat	HL	63.9998	26.21724	48
		LL	82.2309	26.75868	48
		Total	73.1153	27.89744	96
	Total	HL	63.9998	26.21724	48
		LL	82.2309	26.75868	48
		Total	73.1153	27.89744	96
Hanamariam-Maseltegna	Up	HL	70.6104	33.86756	24
		LL	80.7231	33.23894	24
		Total	75.6668	33.58682	48
	Down	HL	62.7667	29.46810	24
		LL	82.4866	24.61822	24
		Total	72.6267	28.64986	48
	Total	HL	66.6886	31.65373	48
		LL	81.6049	28.94884	48
		Total	74.1467	31.08894	96
sarisAbo-Kadisco	Up	HL	66.4827	26.40081	24
		LL	66.8037	29.65449	24
		Total	66.6432	27.77503	48
	Down	HL	66.5890	25.69548	24
		LL	81.5691	25.11425	24
		Total	74.0790	26.24981	48
	Total	HL	66.5358	25.77196	48
		LL	74.1864	28.18964	48
		Total	70.3611	27.13915	96
Kadisco-Bolemichael	Up	HL	57.7956	19.00064	24
		LL	76.6477	30.80292	24
		Total	67.2217	27.05048	48

	Down	HL	50.5066	20.46651	24
		LL	70.6317	27.78162	24
		Total	60.5691	26.19332	48
	Total	HL	54.1511	19.88012	48
		LL	73.6397	29.17628	48
		Total	63.8954	26.69509	96
Boledildiy-Emperial	Up	HL	62.1108	25.50974	25
		LL	91.0218	36.05410	24
		Total	76.2713	34.08030	49
	Down	HL	68.8553	30.69467	24
		LL	81.7977	32.07953	23
		Total	75.1888	31.71790	47
	Total	HL	65.4143	28.07900	49
		LL	86.5079	34.11523	47
		Total	75.7413	32.77606	96
Emperial-Megenagna	Up	HL	83.7559	41.64542	23
		LL	67.4504	25.85273	24
		Total	75.4297	35.09317	47
	Down	HL	64.3738	27.13717	24
		LL	95.4091	18.49843	25
		Total	80.2081	27.74306	49
	Total	HL	73.8587	35.96657	47
		LL	81.7150	26.28238	49
		Total	77.8687	31.47977	96
Total	Up	HL	64.5577	28.95892	216
		LL	75.1679	30.69611	216
		Total	69.8628	30.27505	432
	Down	HL	63.0633	28.35591	216
		LL	80.5966	28.23285	216
		Total	71.8299	29.59307	432
	Flat	HL	62.1538	27.78117	96
		LL	83.5631	26.09611	96
		Total	72.8584	28.94455	192
	Total	HL	63.5093	28.46325	528
		LL	78.9151	29.03810	528
		Total	71.2122	29.75385	1056

APPENDEX F: Questionnaire

1. Category of vehicle you owned

Vehicle with more than four tyre ☐ Vehicle with four ☐

2. Do you use Addis Ababa Midblock ring roads?

Yes ☐ No ☐

3. At what time do you use Addis Ababa Midblock ring roads?

Morning ☐ Mid-day ☐ afternoon ☐ other specify ☐

4. What is your usual speed if the road is free of congestion?

Greater than 80m/hr ☐ 80km/hr-70km/hr ☐ 70km/hr-60km/hr ☐ 60km/hr -50km/hr ☐

Less than 50km/hr ☐

5. what do you decide if you are following slowly moving light vehicle

Change lane freely ☐ change lane uncomfortably ☐ Follow by decreasing speed ☐ other ☐

6. what do you decide if you are following slowly moving heavy vehicle

Change lane freely ☐ change lane uncomfortably ☐

Follow by decreasing speed ☐ other ☐

7. At what time your speed will be interfered by slowly moving light vehicles?

Morning ☐ Mid- day ☐ after noon ☐ other specify ☐

8. At what time your speed will be interfered by slowly moving heavy vehicles?

Morning ☐ Mid- day ☐ after noon ☐ othe ☐

9. Is that availability of curve (horizontal and vertical curve) on that road has an impact on your speed?

Yes ☐ No ☐

10. To what extent?

Highly ☐ moderately ☐ less impact ☐

11. Is that terrain condition of the road has an impact on your speed?

Yes ☐ No ☐

12. To what extent?

Highly ☐ moderately ☐ less impact ☐

13. Is that condition of the road has an impact on your speed?

Yes ☐ No ☐

14. To what extent?

Highly ☐ moderately ☐ less impact ☐

15. Is there any other thing which has an impact on your speed?

Yes ☐ No ☐

16. If yes; what is the other things?

Illegally Crossing pedestrian ☐ malfunctioned vehicles ☐ other specify ☐

17. To what extent?

Highly ☐ moderately ☐ less impact ☐

18. What is impact of following heavy vehicle?

Sight distance problem ☐ discomfort ☐ Enforce to change lane ☐

Other specify ☐

19. What is impact of following slowly moving light vehicle?

Sight distance problem ☐ discomfort ☐ enforce to change lane ☐ other specify ☐

20. If slowly moving heavy vehicle is leading you and unable to overtake; which position is comfortable?

Follow by decreasing speed ☐ side to side using adjacent lane ☐ other specify ☐

21. If slowly moving light vehicle is leading you and unable to overtake; which position is comfortable?

Follow by decreasing speed ☐ side to side using adjacent lane ☐ other specify ☐

APPENDEX F: Format for Secondary data collection

Format for Secondary data in Amharic (safety data)

ቁጥር	የጥፋተኛዉ መኪና ዓይነት(heavy or Light)	ጥፋት የተሰራበት መኪና ዓይነት (heavy or light)	የአደጋዉ ምክንያት	ቦታ(የመጀመርያ አደባባይ እና የመጨረሻዉ አደባባይ ወይም መብራት ስም)
1				
2				
3				
4				
5				

APPENDEX G: Video data record format

No	Segment length (m) A	Front Vehicle time(min.) B	Speed of front vehicle (km/hr) C = (A/B)*0.06	Light (lagging) vehicle time(min.) D	Speed of lagging vehicle (km/hr) E = (A/B)*0.06
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					

23					
24					